

Collapse Operations

FOR FIRST
RESPONDERS

John O'Connell

Fire Engineering®

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PennWell Corporation
1421 South Sheridan Road
Tulsa, Oklahoma 74112-6600 USA

800.752.9764
+1.918.831.9421
sales@pennwell.com
www.FireEngineeringBooks.com
www.pennwellbooks.com
www.pennwell.com

Marketing Coordinator: Jane Green
National Account Executive: Cindy J. Huse

Director: Mary McGee
Managing Editor: Marla Patterson
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Production Editor: Tony Quinn
Book Layout: Susan E. Ormston

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Preface

The purpose of this book is to give suggestions and guidance to smaller fire departments and those with limited personnel, regardless of the response area and civilian population size.

The procedures outlined here are based on the operations-level capabilities as defined in two National Fire Protection Association standards: NFPA 1670, *Operations and Training for Technical Search and Rescue Incidents*, and NFPA 1006, *Technical Rescuer Professional Qualifications*.

Upon arrival at a structural collapse situation, recognize the need for structural collapse search and rescue. Determine the need for extent of and implement a collapse safety zone. Identify the necessary resources needed to conduct your structural collapse search and rescue operations. Initiate your department's standard operating guidelines (SOGs) for control of the collapse site as well as scene management for the incident. Identify the potential hazards associated with these types of incidents. Also be able to identify the different types of construction techniques and building categories. Be able to anticipate the expected behavior of the different components and materials that were used to construct the building. Identify the numerous types of potential collapse patterns and voids, and investigate the possibility of victims being trapped within these collapse voids. Determine the potential for secondary collapse in the remains of the structure. Be able to accomplish visual and verbal searches at an incident by using accepted methods specific to each type of structural collapse. Be capable of implementing a building hazard evaluation marking system as well as a search assessment and victim location marking system, recognized by state and federal government agencies. Have the personnel and capability to access and remove readily accessible and surface victims from structural collapses. Be capable of conducting search and reconnaissance of any surrounding structures potentially affected by the initial collapse incident.

Awareness-level training allows you to identify the situation, request the proper backup and help, and rescue surface victims. Following NFPA 1670 2009 *Edition Operations Level* guidelines: Organizations operating at the operation level for structural collapse incidents shall meet the requirements specified in chapter 6, Structural Collapse Search and Rescue, sections 6.1, 6.2, and 6.3.

Collapse Operations for First Responders

The organization shall have members capable of recognizing hazards, using equipment, and implementing techniques necessary to operate at structural collapse incidents involving the collapse or failure of ordinary construction (light frame, unreinforced masonry, and reinforced masonry construction).

Fire departments operating at the operations level for structural collapse incidents involving light frame, ordinary construction, and/or reinforced and unreinforced masonry construction shall develop and implement procedures for the following:

- Size up existing and potential hazardous or unstable conditions at structural collapse incidents.
- Identify unique collapse or failure hazards specific to each incident.
- Conduct primary (hasty) and secondary search operations (low and high coverage) intended to locate victims trapped on, inside, and underneath collapse debris.

- Have the capabilities to access any victims trapped inside and underneath the collapse debris.
- Be able to conduct extrication operations involving packaging, treating, and removing victims trapped within and under collapse debris.
- Size up the structure and be able to perform rescue shoring operations in order to stabilize the structure when necessary.

Note: The training identified in chapter 6 section 6.3.1 is necessary before your department operates at the level described in section 6.3.

Operations-level training allows you to identify the situation, request the proper backup and help, and rescue surface victims. It also allows your responders to search and rescue any victims in any void situations as well as conduct proper shoring operations. This only applies to the types of structures identified above.

Glossary

30° angle. The lowest angle that should be used in emergency raker shoring.

45° angle. The preferred angle to use for the raker shore due to its efficiency and ease of construction.

60° angle. The steepest angle that should be used with raker shoring during rescue shoring operations.

abutment. Originally used to describe the end support of an arch or vault. Now it describes any support that receives both vertical and lateral loading.

adjustable square. A try square whose arm is at right angles to the handle. The position of the arm may be moved to form either a T or an L shape.

A-frame. A type of collapse caused when bearing walls separate from the floors while an interior bearing partition still functions. It can leave people trapped in voids along those partitions or in the debris on the floor above.

air compressor. A machine that can draw in outside air at atmospheric pressure then compress that air to pressures higher than the normal atmosphere, and deliver it at a rate great enough to operate pneumatic tools and equipment. It usually runs on gasoline or electric power.

air-dried lumber. Wood dried by the exposure to air under natural conditions. This lumber usually does not have a moisture content greater than 24%.

allowable load. The load that induces the maximum allowable unit stress at a critical section of a structural bearing element.

alterations. Construction in a building consisting of revisions that may change the structural elements of the building. These revisions may include moving mechanical equipment, columns, bearing walls, or the locations of openings such as doors and windows. However, it does not increase the overall area or dimensions of the structure. This is one of the most common causes of building collapse.

anchor bolt. A steel bolt usually fixed in a building's structure with its threaded portion projecting. It is used to secure frameworks, timbers, machinery, and the like. It can be used to anchor the wall plates of raker shores to stop any upward movement of the shores.

arch. A curved type of construction that spans an opening, usually consisting of wedge-shaped blocks or a curved structural member that is supported at both ends. Arches vary in shape from semielliptical to the acutely pointed type. Failure of any element in an arch may cause total arch failure.

axial force. The action of compression or tension along the length of a structural member, usually expressed in pounds. A load applied to the center of a structural member such as a column or strut.

axial load. The resultant longitudinal internal component of force that acts perpendicular to the cross section of a structural member and at its center, producing uniform stress throughout that element.

balloon framing. A system of framing a wooden structure in which all of the vertical structural elements of the exterior bearing walls and partitions consist of single studs. These studs extend the full height of the frame, from the top of the soleplate to the roof plate, and all the building's joists are fastened to these studs with nails.

beam. A structural element that sustains transverse loading and develops internal forces of bending and shear in resisting loads. Also called a girder if large scale; a joist if small scale or closely spaced in sets; a rafter if used for a roof.

beams. Horizontal or inclined load-carrying structural members, supported on two or more points. A structural member whose prime purpose is to carry transverse loads.

bearing wall. A wall that supports a vertical load other than its own weight. These walls may be located anywhere in the structure, but generally are located as the exterior walls.

bending. A combination of two states of stress, compression and tension, in different fibers of the same structural element. It is the turning action that causes change in the curvature of a linear element. It is

probably the most common state of stressing you will see in collapse operations.

bevel square. A carpenter's tool, similar to a square but with a blade on one end that can be adjusted to any angle. It is an excellent tool for transferring preexisting angles to other pieces of lumber.

board foot. In lumber, a unit of measure equivalent to a board 1 foot square and 1 inch thick.

boards. Dimensional lumber that is 2 or more inches wide and 1½ inches thick or less.

bottom plate. See soleplate.

brace. A metal or wood member that is used to stiffen or support a structure; a strut that supports or fixes another member in position or ties together several members at once.

braced frame. The use of heavy braced wood framing for a structure that uses girts that are mortised into solid posts. These posts are the full frame height of the building. One-story-high studs are usually placed between them and diagonally braced.

bracing. Resistance to movements caused by lateral forces or by the effects of buckling, torsional rotation, or sliding.

bridging. Blocking that is used between floor joists and rafters to keep the members from twisting.

buckling. Collapse, in the form of sudden sideways deflection, of a slender element subjected to compression.

built-up member. A single structural component made from several pieces fastened together.

camber. The name given to the bend in a beam that was created when the beams was placed under stress. In prestressed concrete construction, members have a natural tendency to bend in a vertical plane, so the midpoint is higher than the ends. This curvature is called a camber and results from the eccentric application of the prestressed load. Both prestressed and posttensioned concrete members will camber.

cantilever. A beam, girder, truss, or other structural element that is projected beyond its supporting wall or column.

cantilever beam. A beam that is generally supported only at one end. The compression force on this type of beam is the opposite of that of a supported beam.

carpenter's level. A device used by carpenters to determine an even horizontal or vertical line, consisting of a spirit level set in a wood or metal frame.

center brace. A strip of wood usually 1×6 of $\frac{3}{4}$ -inch plywood nailed in the center of the vertical shore or laced post for additional stability. Normally called midpoint bracing.

chain saw. A power-driven saw, either gas, electric, or hydraulic, usually handheld for cutting wood. A protruding arm carries a continuous chain in which different types of cutting teeth are set.

checks (lumber). Splits or cracks in a board, generally caused by drying or seasoning too rapidly. A separation of the wood naturally occurs across or through the growth rings.

circular saw. A power saw, normally electric, in the form of a circular steel blade with different shapes and numbers of teeth along the perimeter along the blade, $7\frac{1}{4}$ -, $8\frac{1}{2}$ -, and $10\frac{1}{4}$ -inch are generally the sizes used in rescue shoring.

cleat. A small block of wood usually 2 inches thick nailed on a member or a surface, used to stop another member from moving or sliding. Generally 12 inches to 30 inches in length, usually a 2×4 or 2×6 .

CMU. Concrete masonry unit, which is regular concrete block.

collapse. The sudden and rapid failure of a structural member or structure due to a variety of forces or reasons.

column. In standard building construction, a relatively long, slender structural element under compression, usually vertical. Normally, a column supports a load that acts in the direction of its longitudinal axis. If this load should shift and the column becomes unevenly loaded, it could fail by buckling.

combination square. An adjustable carpenter's tool consisting of a steel rule that slides through an adjustable head. It can be used as a try square, marking gauge, and straight edge.

combined load. Two or more different types of loads impacting on a structure at the same time, such as dead load, live load, and wind load.

combined stress. The combination of axial and bending stresses acting on a member simultaneously.

common nail. A cut or wire low-carbon steel nail having a slender plain shank and a medium diamond tip, generally used in framing and utility work.

compound beam. A built-up rectangular beam composed of smaller timbers over which planks are nailed on each side. The entire unit is then joined together by bolting.

compression. The force on a structural member that has a pushing or *compressive* effect on the member and its end connections. It is the state of stress where the particles of the material are pushed one against the other. It generally causes overall shortening of objects in the direction of its action.

compressive strength. The maximum compressive stress force that a specific material can handle before failure.

compressive stress. The stress that will resist the shortening effect of an external compressive force.

concentrated load. A load acting on a small, localized area of a structure; a load that is applied unequally over an area. The opposite of a distributed load.

connection. The result of joining of two or more distinct elements. In a structure the connection itself often becomes an entity.

continuous beam. A beam that can extend over three or more supports and can support a continuous load evenly.

cribbing. A framework constructed of timbers or steel to provide support for material above it. In urban search and rescue, it is the assembly of multilayers of dimensional lumber used to support and stabilize damaged structural elements or specific items.

cripple stud. A structural element that is shorter than usual, for example, a stud in a short wall or above a door or window opening.

cross bracing. A system of bracing in which there are intersecting diagonals, also called X bracing. Used with vertical shores, horizontal shoring, and raker shoring.

cross grain. Lumber grain that is not parallel to the axis of the member. This characteristic is undesirable because it lessens the strength of the wood.

crush injury syndrome. A condition that occurs in trapped victims due to a combination of kidney failure, muscle destruction, and shock. The extended compression of muscle tissue from entrapment leads to the release of toxins into the circulatory system, which can lead to death when the victims are freed.

curtain wall. A non-load-bearing wall built between exterior columns and beams. It is supported entirely by the frame of the building rather than self-supporting.

dead load. The overall weight of a structure itself including the weight of any fixtures or equipment permanently mounted within. HVAC (heating, ventilation, and air-conditioning) or a safe in a bank is considered a dead load.

dead shore. An upright series of timbers used as a support for a dead load during structural instability. Another term for interior vertical shore.

deck. The flooring of a building or other structure or an open platform, regardless of what type of construction it is.

deflection. The lateral movement of a structure caused by loads. It reflects the amount of deformation of a member and the displacement of a structural member as a result of loads applied to it. Examples are the vertical sag of a beam and the lateral sway of a tower.

deformation. Any change in the shape, including shortening, lengthening, twisting, buckling, or expanding, of a structural element without breaching the continuity of its parts.

design loads. The total dead and live loads that a structural member is designed to support.

diagonal brace. An inclined structural member in compression or tension, usually installed to stabilize a framework against the horizontal forces that may be applied to it. Can be used in almost any type of shoring.

direct stress. Stress without bending or shear; it includes only compressive and tensile stress.

distributed load. A load that is applied evenly over a given area. Buildings are designed to function with this type of load. If an evenly distributed load becomes concentrated, a collapse could occur.

door shore. A series of uprights and lateral pieces of lumber used to stabilize a door opening for access by rescue personnel; generally constructed of 4 × 4 lumber and 2 × 4 wedges.

double-headed nail. A scaffold or form nail having two heads, one above the other. The upper head is driven with a hammer until the lower head bears on the surface into which the nail is driven. The space between the upper and lower head is then used to withdraw the nail. This nail is used for temporary work and is excellent for erecting shoring for training purposes.

double T shore. A temporary safety shore, constructed with two posts instead of one and 12-inch by 24-inch gusset plates. Stronger and more stable than the single-post T shore.

dry rot. Deterioration of wood caused by fermentation and chemical breakdown when attacked by fungus.

dry wood. Any wood that has been dried to a moisture content of 15% to 19%.

ductile. Describes the strain behavior that results from the plastic yielding of materials or connections. To be significant, the plastic strain prior to failure should be considerably more than the elastic strain up to the point of plastic yield.

duplex head nail. Same as double-headed nail.

dynamic load. Any load that is nonstatic or movable; a load that changes location or value rapidly, such as the wind or a moving live load. An elevator is an example of this type of load.

earthquake collapse patterns. Caused by the extreme motion of earthquake. Massive tension, shear, and torsional and compression forces can be created, causing specific structural elements in a building to fail. The failure of these elements, generally at connection points, can cause total or partial collapse of a structure.

earthquake load. The total force that is exerted on a structure by the actions of an earthquake.

eccentric. Not having the same center line or bearing.

eccentric load. A load normally on a column that is nonsymmetric with respect to the central axis of the column, thereby causing a bending action.

elastic. Used to describe two aspects of stress-strain behavior. The first is a constant stress-strain proportionality, or constant modulus of elasticity, as represented by a straight line form of the stress-strain graph. The second is the limit within which all the strain is recoverable; that is, there is no permanent deformation.

elasticity. The property of a body that causes it to tend to return to its original shape after deformation from stretching, torsion, or compression.

face nailing. The direction of nailing in which the nails are driven perpendicular to the face of the material.

failure. The condition of becoming incapable of a particular function. Structural failure may be partial or total. For example, a single connection may fail, but the structure might be able to redistribute the load and thus might not collapse.

fatigue. A structural failure that occurs as the result of a load applied and removed or reversed repeatedly through of a large number of cycles.

FEMA. Federal Emergency Management Agency, the U.S. government agency that is in charge of the Urban Search-and-Rescue (US&R) taskforces throughout the United States.

fish plate. A piece of wood or metal that is used to fasten together the ends of two separate members with nails or bolts.

fixed beam. Both ends of a fixed beam are built into a rigid element, preventing the beam from rotating. This beam is 50% stronger than a simple beam of the same size.

flitch plate. A steel plate that is sandwiched between two pieces of structural lumber and bolted together.

force. In building construction, an effort that tends to change the shape or the state of motion of an object.

framing square. See steel square.

flying shore. A large shoring system placed between two buildings for temporary support, generally above the first floor. A rather complicated setup that is not often erected.

flying raker shore. An initial shore erected in place before a series of raker shores is to be assembled, used to make the area safer for rescue operating personnel.

girder. A major horizontal member used to carry a series of beams or a large load. Generally, a girder is a beam that supports other beams, normally at right angles to those beams.

grade beam. A horizontal structural element in a foundation system that serves some spanning of load-distribution function.

grades of lumber. Classification of lumber according to strength and utility.

green lumber. Freshly sawn or unseasoned lumber that has not been dried.

gusset plate. A section of plywood, generally $\frac{3}{4}$ inch thick used to hold two separate pieces of lumber that are connected together from moving or dislodging.

half gusset. Typically a section of $\frac{3}{4}$ -inch plywood, 6 inches wide by 12 inches long. Used mostly in interior shoring to box in wedges.

hardwood. Lumber that comes from broad-leaved deciduous trees, heavy and close grained. Oak and maple are two common types.

header. 1. In general, the upper horizontal cross member between the jambs, which forms the top of a window or door frame and provides structural support

for construction above. 2. The designation given to the top member in vertical, window, door, and laced post shores.

heart lumber. The dense wood in the center portion of a tree, surrounded by softer sapwood.

horizontal brace. The term used for the horizontal truss system used to anchor a series of raker shores together.

horizontal shore. Any shore interior or exterior that supports unstable walls with the use of two wall plates and two to three horizontal struts.

I-beam. A common name for the American standard beam because of its resemblance to the letter “I.”

ICS. Incident Command System, also known as the Incident Management System (IMS).

impact load. The dynamic effect on a structure of forcible momentary contact with another moving body. It is one of the most dangerous loads we will encounter in collapse situations.

IMS. Incident Management System, also known as the Incident Command System (ICS).

initial safety shoring. The installation of any temporary safety shoring before the main shoring has begun.

jack beam. A horizontal member used to support another beam or truss and eliminate a post.

joist. One of a series of parallel beams of timber, steel, or reinforced concrete used to support floor and ceiling loads, and supported in turn by larger beams, girders, or bearing walls. The widest dimension of the joists is vertically oriented.

kiln-dried lumber. Wood that has been seasoned in a special chamber by artificial heat.

laced post shore. Another name for the shore tower, used to support heavy concentrated loads. The strongest and most stable shore your team can erect.

lateral. To the side of or from the side; perpendicular to a major axis or direction. In collapse situations, lateral refers to the direction that is perpendicular to the vertical direction of gravity. Lateral forces include wind, earthquakes, and the like.

lateral bracing. Either horizontal or vertical bracing for a wall, beam, structural member, or shoring. Usually consists of 2 × 4 or 2 × 6 dimensional lumber.

lean-to. A common type of collapse pattern that occurs in several types of buildings. This occurs when one exterior wall lets go, causing the floors supported by that wall to drop and lean on debris below.

level. The position of a line or plane when that line is parallel to the surface of still water.

lintel. A horizontal structural member placed over an opening in a wall, such as a door or window, to carry superimposed loads.

live load. Any load other than the dead load, such as snow, wind, people, and temporary loads.

load. A force or systems of forces that are exerted on or carried by a structure or part of a structure. The active force of combination of forces exerted on a structure.

member. In building structures, the name of one of the distinct construction elements.

midpoint brace. Used in vertical shoring and laced post shores as additional lateral support when the posts reach a designated height. It is usually a 1 × 6 piece of lumber or a piece of ¾-inch plywood. Also called center bracing.

moment. Also called torque. Action tending to produce rotation; moment is the product of a force times a distance. Bending moment causes curvature, and torsional moment causes twisting.

mud sill. A plank or timber laid directly in mud or soft soil, used to help distribute the weight of an object above it.

nail. A straight, slender piece of metal, that is pointed and has a head, usually made of steel. Normally driven with a hammer and used to hold two or more pieces of lumber together.

neutral axis. An imaginary line in a beam, shaft, or other member, subjected to bending where there is no tension or compression and where no deformation has taken place.

NFPA. The National Fire Protection Association, an organization that issues standards for the fire service. NFPA 1670 and 1006 are the two standards that are concerned with structural collapse rescue.

NIMS. National Incident Management System is a structured framework that is used throughout the United States for both governmental and nongovernmental agencies to respond to natural disaster and or terrorist attacks at the local, state, and federal levels of government. It is designed to be used by any and all response agencies, keeping everyone on the same page.

nominal size. The dimensions of sawn lumber before it is dried or surfaced.

offset collapse. Normally occurs in light frame construction when the exterior walls lose their sheathing and shear strength, which causes the studs to separate and the rest of the building to lean over.

ordinary construction. A type of construction in which the exterior bearing walls are made of noncombustible materials. The roof, floors, and interior framing are wholly or partly constructed of wood.

overturn collapse. Happens primarily in earthquake situations. It can be caused by liquefaction or by failure of exterior wall columns in tall, slender structures. The lower floors either partially collapse or sink, causing the building to lean drastically or completely overturn.

pancake. A collapse pattern that develops from bearing wall failure or a sudden impact load on the roof or upper floors.

parapet. The extension of a wall plane or the roof edge facing above the roof level. Most often seen in unreinforced masonry structures.

penny. A unit denoting the length of a nail and also an indication of the shank and head diameter.

pilaster. An integral portion of the wall that projects on one or both sides and acts as a vertical beam, column, architectural feature, or any combination thereof.

pitch. The slope or angle of the raker shore. A point 9 feet high and 12 feet back is a 9 on 12 pitch.

plastic. In structural terminology, plastic refers to the type of stress response that occurs in ductile behavior, usually resulting in considerable, permanent deformation.

platform frame. Sometimes called western frame, it is a framework in which the studs are only one-story high, the floor joists of each story rest on the top plates of the story below, and the bearing walls and partitions rest on the subfloor of each story.

plumb. Exactly vertical; the right angle to a level line exactly 90° to that line.

plywood. Structural wood made of three or more layers of veneer, usually an odd number. Generally laid with the grain of adjoining plies at right angles glued together.

post. The vertical members in T, double T, laced post, window, door, and vertical or dead shoring; the main elements that transfer the damaged loads to good bearing.

primary structural members. The various elements that support the main structure of a building or other structural members. Columns, arches, beams, girders, and bearing walls are considered primary structural elements.

punching shear. The punching of a hole through a base by a heavily loaded column as a result of failure of the base. This can easily happen in rescue shoring if the loads are not properly distributed.

purlin. A building element laid horizontally on the main beams of a roof to support the common rafters on which the roof covering is laid.

raker. The main element in raker shoring, a raker is the diagonal member that transfers the load of the damaged wall to good ground. Can be installed at a 45° or 60° angle.

raker shore. A type of rescue shoring used to stabilize the leaning walls of a structure, utilizing an inclined member. The solid-sole, split-sole, and flying raker are the three main types.

random fall collapse. Usually occurs in earthquakes and happens mainly to precast connected buildings, such as parking garages. The shaking of the

earth causes the connection points of the building's elements to fail and causes progressive failure due to the weight of the elements. It is hard to predict how these structures will collapse, hence the word *random*.

reciprocating saw. A power-driven saw (electric, gas, or pneumatic) with an oscillating blade that extends through the front of the saw, an invaluable tool in collapse operations.

renovation. The restoration of an existing structure that does not create any structural changes to that building. It is generally cosmetic in nature and includes replacement of windows, new ceiling coverings, or new interior or exterior wall coverings. This type of operation does not usually have many collapse hazards.

rescue struts. Pneumatic shores that can quickly be set up in collapse situations and are easily manually adjusted. They can withstand pressures of more than 50,000 lb.

rigid frame. A framed structure in which the joints between the members are made to transmit moments between the ends of the members. Joints in this type of structure are fixed and can transmit forces more readily from point to point.

roof lift-off collapse. Generally occurs in natural high-wind incidents. In light frame and heavy wall construction, this pattern will develop when the roof is lifted off of the structure due to aerodynamic lift or having the wind penetrate the structure.

safe load. The load on a structure that does not produce stresses in excess of those that the building can safely support.

screw. A fastener with an externally threaded shaft; has slightly better holding power than a nail.

shake. A defect in wood, usually a split or crack; the result of damage during growth or unequal shrinkage during drying.

shear. A deformation in which parallel planes slide relative to each other so as to remain parallel. A force effect that is lateral (perpendicular) to the major axis of a structure, or one that involves a slipping effect, as opposed to a push pull effect. Wind and earthquake forces are sometimes visualized as shear effects on a building. This is because they are forces perpen-

dicular to the major vertical axis of the structure, namely gravity.

shear strength. The maximum amount of shear stress that a material is capable of handling before permanent failure results.

shims. Thin pieces of wood or metal, usually tapered, which are inserted under one member to adjust its height or to fill in an open area.

shoring. The application of materials, normally wood, to temporarily support a damaged structure. The temporary support of structures during construction, demolition, alteration, renovation, and so forth, in order to provide the stability that will protect property as well as construction crews and the public.

rescue shoring. The erection of a series of timbers and bracing to stabilize walls or floors in an attempt to stop any further movement or collapse of unstable structures. It is strictly a temporary measure, used to provide a degree of safety for rescue personnel operating in unstable structures. It is not used to restore structural elements to their original positions or shapes.

shore tower. A substantial shoring setup that is used when a large concentration of weight is located in one spot above. Another name for the laced post shore.

sill. A horizontal timber at the bottom of a wood structure that rests on the foundation or ground.

simple beam. A structural beam having its ends free and resting only on supports on each end.

sleeper. Any long horizontal beam on the ground that distributes the load from the members above.

soft story collapse. This pattern will develop in a structure where the first floor is open and does not contain many shear-resisting walls, while the upper floors do. The earthquake motion becomes concentrated in the minimal shear wall of the lower floor, causing it to fail. The upper stories with their shear walls can still be connected and will collapse as a unit on to the soft first story.

softwood. Lumber derived from trees with a needles or scalelike leaves.

soleplate. The designation given to the bottom member in a solid-sole raker shore, vertical shore, T shore, double T shore, two-post vertical shore, laced post shore, and window and door shore.

solid-sole raker. One type of raker shoring normally used on concrete or hard surfaces. It is the raker shore of first choice, usually constructed of 4 × 4 lumber.

spandrel wall. Part of a panel wall above the top of a window in one story and below the windowsill of the story above.

spirit level. A closed glass tube of circular cross section usually set in an instrument or device. The tube is nearly filled with liquid so that a bubble is formed, the center of which is used to determine true horizontal or vertical directions. Commonly called a level.

split. The separation of wood due to wood cells tearing apart.

split-sole raker. Another type of raker shore that is normally used when soft ground is encountered.

squad. A smaller group of firefighters; subdivision of a team. Usually under the direction of an officer. The typical squad consists of five firefighters and an officer.

static. The state that occurs when the velocity is zero; thus no motion is occurring. Refers to situations in which no change is occurring.

static load. Any load placed on a structure that does not change in magnitude or position with time; a load that remains constant and is applied slowly.

steel square. A right angle tool that is 24 inches long and 2 inches wide on one end, and 16 inches long and 1½ inches wide on the other. The tool has several scales and tables that a carpenter can use for many functions. It is excellent for use in the construction of raker shoring.

strain. A change in the shape or form of a body or material that is subjected to an external force. Deformation resulting from stress is usually measured as a percentage of deformation, sometimes called unit strain or unit deformation.

stress. The internal force set up at a point in an elastic material by the action of external forces. The mechanism of force within the material of a structure; visualized as a pressure effect, tension, compression, or shear effect on the surface of a unit of the material and quantified in units of force per unit area. Allowable, permissible, or working stress refers to a stress limit that is used in stress design methods; ultimate stress refers to the maximum stress that is developed just prior to failure of the material.

stringer. A long horizontal member that supports a floor or deck.

structural collapse technician. Usually identified by the abbreviation SCT. This individual is a highly trained firefighter who has completed at least 100 hours of training in structural collapse rescue as well as numerous other disciplines. Defined in NFPA 1006 for the rescuer and NFPA 1670 for the response agency.

strut. A brace or any piece of material that resists thrusts in the direction of its own length; it may be vertical, diagonal, or horizontal.

stud. An upright post or support; normally one in a series of vertical structural members that act as the supporting elements in a wall or partition.

supported lean-to. A collapse pattern caused by bearing wall failure or floor beams pulling away from their supports. The floors in question will be supported in both directions.

team. A group of firefighters; a team can be as few as two individuals or as many as necessary. They are organized under specific commands and one leader.

tensile strength. The resistance of a material to rupture when subject to tension; the maximum tensile stress that the material can sustain.

tension. The force exerted on a structural member that has the effect of either pulling apart or elongating the structural member in question. Produces straightening effects and elongation.

tilt-up. A precast concrete panel that is lifted and set in place by a crane, usually used in commercial warehouse-type construction.

timber. Lumber that is 5 inches or more in its least dimension.

thrush blocks. Another term for the top and bottom cleats used in the raker shoring.

toenail. A method of anchoring two sections of lumber by driving the nails on a slant or at an angle into each other.

torsion. The twisting of a structural member about its longitudinal axis by two equal and opposite torques, one at one end and one at the other. Lateral loads produce torsion on a building when they tend to twist it about its vertical axis. This occurs when the center of the load does not coincide with the center of stiffness of the vertical elements of the lateral load-resisting structural system.

torsional load. A load that creates a force that is offset from the shear center of that section and causes a twisting of that element.

transit. A surveying instrument used for the measuring and laying out horizontal and vertical angles, distances, directions, and differences in elevations. Excellent for determining the slightest movement in a collapsed structure from a safe distance away.

truss. A structure composed of a combination of members, usually in a triangular arrangement to constitute a rigid frame work.

T shore. A shore normally erected out of 4 × 4 lumber in the shape of a T and used mainly as an initial safety shore. It has a maximum header length of 36 inches.

ultimate strength. The maximum static force resistance of a structure at the time of failure.

ultimate stress. The maximum stress that a material can stand before it breaks apart.

uniform load. A load that is equally distributed over a given length of a structural member.

unsupported lean-to. The cause of this type of collapse is the same as that of the supported lean-to. The failed ends of a floor hang precariously with no solid support. Supporting the free end must be done before any rescue operations are attempted. It is one of

the most dangerous types of collapses that your rescue team can encounter.

vernacular. A term used for the technique of building that is done according to local custom, not engineered to exacting specifications.

vibration. In building construction, it is the cyclic, rhythmic motion of a body such as a spring and occurs when the body is displaced from some neutral position and seeks to restore itself to a state of equilibrium when released.

voids. The open spaces left in structures after they have been subjected to the damages of collapse. The area to be searched first in a building, where there is the best chance of victim survival.

vertical shore. Sometimes known as a dead shore; used to support any loads from floors above in a damaged structure. It is the most common type of shore erected in ordinary constructed buildings.

V-shaped. One of the common types of collapse patterns that occur, generally caused by the failure of an interior bearing member.

wall. A vertical, planar building element. Foundation walls are those that are partly or totally below ground. Bearing walls are used to carry vertical loads in direct compression. Shear walls are those used to brace the structure against horizontal forces due to wind or seismic shock.

wall fall collapse. Depending on the type of construction, unreinforced masonry (URM) or heavy wall, this pattern will develop when earthquake motion overcomes the building's connection points. The walls can then fall outward. In weaker URM construction the upper sections of the buildings walls will fail first.

wall plate. Used in raker shoring and horizontal shoring, the first members erected against damaged walls that are to be stabilized.

wall tilt-up collapse. Will occur in tilt-up wall construction, generally warehouse-type construction. If a failure of the roof connections occurs, the walls normally have little lateral support, and they will lean out or fall, sometimes as a unit.

wedges. Pieces of wood or other material thick at one end and tapering to a thin edge at the other; used in pairs to take up the space between supporting members.

wind load. The total force exerted by the wind on a structure or part of a structure.

wind load collapse. The result of a wind shear or torsional overload against a structure causing that structure to partially or totally collapse. Structural members are then overstressed and fail; generally connection points of the buildings structural components would be the first to fail.

window shore. Any shores that support an unstable window opening through the use of timbers and wedges. Normally constructed of 4 × 4 lumber and 2 × 4 wedges.

wood frame construction. The construction in which exterior walls, bearing walls and partitions, floor and roof constructions, and their supports are made of wood or other combustible material; the construction does not conform to ordinary or heavy timber situations.

working stress. The unit stress that has been shown to be safe for a specific material while maintaining a proper degree of safety against structural failure.

yield stress. The amount of stress that will result in permanent deformation.

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Warning Signs, Causes, and Safety Precautions of Building Collapse

Introduction

Although structural collapse happens suddenly, it rarely occurs without a warning sign, be it subtle or obvious. Warning signs may occur at any incident, and each incident will dictate which warning signs need to be addressed first. Generally, this decision will be based on the initial cause of collapse or the major hazard that precipitated the rescue response. Some collapses are caused by structural anomalies or forces of nature. The following are some of the more common indications of possible building failures in typical structures, including some that may lead to secondary collapse, a major concern when operating at a collapse incident:

- Bulging walls
- Cracks in plaster or masonry walls
- Leaning walls
- Unusual sounds
- Sliding plaster or airborne dust
- Vibrations or rumblings
- Sagging floors or roof
- Walls separating from each other or the ceiling
- Columns out of plumb
- Doors swinging open or closed
- Racked buildings
- Door and window frames out of square
- Severe weather conditions
- Missing or broken structural elements



The bottom line is that any visible deformation of a structure can be dangerous. The force of gravity is always acting to cause a deformed building to fail. The building may be at rest after the initial collapse, but any of the items in the preceding list can contribute to a secondary collapse of the building's remaining structural elements. It is vital to identify the warning signs of possible collapse early on.

Collapse Warning Signs

Bulging walls

A bulging wall can be extremely dangerous, especially if it is a bearing wall. The floors above it and the roof depend on the integrity of the bearing wall to hold them up. Remember, most beams extend out onto bearing walls less than 12 inches, and many only 3 to 4 inches. Any additional shifting of bulging or leaning walls may cause a major collapse to occur. These walls must be examined, and corrective measures must be instituted immediately. Even the remaining intact walls should be examined; the damaged section of wall was caused for some reason, and that reason may be affecting the rest of the wall. A leaning wall also loses quite a bit of its strength, because the wall is being eccentrically loaded by forces it was not designed to support.

Cracks in walls

A traveling crack in a wall is a major indicator of impending failure, because it signifies an increasing load on the structure that is pushing it to its failure point. Fresh cracks in walls indicate new damage, and old cracks mean that previous stress and settling have occurred in the structure, making the entire building's stability questionable. Both need to be investigated. When obvious signs of cracking have occurred, especially in masonry, the wall will react differently. The wall is no longer an integral unit but a section of numerous individual ones. This makes the wall unstable and a possible collapse hazard. Although concrete does normally crack, severe cracks that are deep or wide or that show exposed rebar are definitely a problem. In that case, structural integrity has been lost, causing weakening of the wall in question (fig. 1-1).



Fig. 1-1. A crack in a concrete block wall. This crack in the corner front of this structure creates a very dangerous situation for the stability of the entire corner of this structure, given that it is supported only by the steel and column.

Cracks in columns, beams, or foundations

Figure 1-2 shows two supporting beams with spiral cracks. These spiral cracks indicate a very dangerous situation because they show that a major overload was applied to both beams. This is a very unstable situation given that both of these beams have basically failed and are holding up a fraction of the weight they were designed for. The beams need to be shored up immediately to prevent a potential collapse. If the responding teams do not have shoring capabilities, evacuation procedures may need to be initiated and a collapse safety zone set up while waiting for shoring capabilities to arrive.



Fig. 1-2. Two supporting beams with spiral cracks

Leaning walls

Walls that are visibly leaning can pose a substantial problem. If you can see that the wall is out of plumb, you have a potentially dangerous situation. Walls have been known to fail when out of plumb by only 10%, especially older masonry walls. The other issue with walls that are leaning is that the beams and joists above are not supported properly. The beams and joists can slide off the leaning wall, causing the entire floor to collapse.

Figure 1-3 shows the results of foundation undermining caused by erosion of sand from under the building. A category 4 hurricane and tidal surge removed the supporting material from under the building. As a result, with the foundation sinking and shifting, the whole structure leaned over to one side. Rescue and search teams must be extremely careful in their size-up of a building in this condition. When entering for search, check that the interior and partition walls are all still anchored to each other. If so, the building may still be stable enough to search without a major risk of secondary collapse. If all the walls have separated from each other, then the structure would be nothing but a house of cards, making an interior search very dangerous if not impossible. Remember, there could be good sections of the building that are still searchable and bad sections on the same floors or general areas. Each area must be evaluated as operations expand. The stability of the structure must be monitored continually while rescue forces are on the scene. Look for more settling and shifting to occur.



Fig. 1-3. The results of foundation undermining due to erosion of sand from under the building, caused by a hurricane and tidal surge.

Unusual sounds

Groans, creaks, and rumblings are some of the sounds of an unstable building. These sounds come from the intense strain on large structure-bearing members as they are overloaded to the point of failure. If these sounds are heard, the structure should be evacuated immediately. This is an imminent sign of collapse and must be addressed right away.

Sliding plaster or airborne dust

Rising dust will occur when beams and walls strain and move. When this happens, the dust tends to stay airborne and float throughout a room. This can indicate that beams and joists are pulling away from their supports, popping the nails holding them together. As wall studs are pulled and twisted, the lath loosens, causing more dust. When movement and strain are severe, sections of the plaster will actually dislodge and fall out. As you search throughout the building, keep an eye on debris on the floor—it could be plaster that has fallen off the walls or ceilings.

Vibration

Buildings are not normally built to withstand extensive vibration. For example, a vibration caused by an earthquake will easily bring down a building by literally shaking it apart. Long-term vibration from machinery also can damage structural hangers and connectors, ultimately causing beam failure. Nails and bolts will most certainly loosen up when under constant vibration.

Sagging floors and roofs

Sagging is a sign of major structural damage and can be caused by a number of factors, including age, weather exposure, lack of maintenance, and overloaded conditions. Even the weight of a rescuer or a small impact load can bring about a collapse. When floors sag, they place an undue stress on the connection points to the walls or columns supporting them, which can potentially cause a collapse. Wooden beam floor joists that sit on masonry or concrete actually shorten in length as floors sag. This has the potential to cause the beams slide off their supporting walls, causing extensive collapse.

Figure 1-4 shows an interior brick support pier that let go, and as a result, the floor section dipped down well over 12 inches. This caused an interior partition on the floor to fail and lean into the center of the building. Before searching the floor areas, check the area underneath the floor. Check for stability, as well as instability, and crib or shore up where necessary. This has to be accomplished before any operations can occur above the floor. The floor section must be secured from further collapse before rescue personnel can enter and search.



Fig. 1-4. An interior brick support pier let go, and the floor section dipped down more than 12 inches, causing an interior partition on the floor to fail and lean into the center of the building.

Figure 1-5 shows exterior walls that have collapsed, causing a metal deck roof with steel trusses to sag down onto storage racks and debris. The lightweight roof stayed together while some trusses tore away from the roof decking, leaving large sections of this roof hanging free. Searching under this roof may or may not be a problem, depending on what is holding it up and how well the trusses are still connected to the roof decking. In some cases, a few well-placed shores under the truss sections may be all that is needed to pronounce this roof “safe.”

Separation of walls and ceilings

In most structures, all of the walls are tied to each other and the ceiling. Any separation of these elements in the corners indicates movement of floors or exterior walls and excessive stress on the structure-bearing members, which may lead to the building’s failure. These separations are easy to spot as soon as you walk into a room, and they are generally larger at the top of the wall than at the bottom.



Fig. 1-5. In this situation, the exterior walls have collapsed, causing the metal deck roof with steel trusses to sag down onto storage racks and debris.

Columns out of plumb

Whenever you notice a column out of plumb, there is a potential problem and possible collapse in the making. All columns are designed to support their full load in a vertical position. As long as a column is vertical and plumb (level in a vertical plane), it will function properly. As movement occurs, or some other force has changed the column’s orientation out of plumb, the column loses efficiency and thus strength. The more out of plumb the column is, the less it can hold up, and at some point it will fail. Another issue with an out-of-plumb column is that the items it is holding up will most likely fail without the column’s support. Many times a connection joint is above the column, and this joint needs the support of the column to hold itself together. If the column moves only a few inches, then the joint can easily fail. If that happens, both will drop, causing a collapse of some type. If the column gets knocked out of plumb, then the bearing of one or both of the beams will be compromised, possibly causing a structural collapse.

It is also important to determine whether there is any belly, or deflection, in a column. This will drastically diminish the strength and stability of a column. Check for deflection as soon as possible, especially with long, thin columns. The longer and thinner the column, the faster and more easily it will deflect, causing structural problems to occur rapidly. Columns that are still holding up with no deflection but are damaged must

be watched extensively. The damaged areas compromise the strength of the column, and these areas will be the first places where the column will fail.

Doors swinging open or closed

In severe collapse situations, doors will swing open and closed. One of the most famous cases of this occurred in Harlem in New York City in the early 1990s. Just before the building's floors collapsed, the structure racked, and the opened doors to the hallways swung shut. As the building leaned and racked, the doors did not shut all the way, but jammed into their openings. Immediately after this occurred, the interior floor sections collapsed down five stories, taking all the floors into the basement. This caused floors and debris as well as building contents to pile up to the middle of the second-floor level. The reinforced stairwells actually stayed intact. When a structure twists or leans out of plumb, any open doors that are still free-hanging will have a tendency to swing in one direction or the other. In most cases, they will jamb into the now out-of-level floors if the lean or twist is severe enough.

Racked buildings

The results of some incidents, such as foundation failure, explosions, or natural disasters, can easily rack any structure. When racking occurs, the building is either shifted (twisted) off of its foundation or the foundation loses its ground support and sinks unevenly. For whatever reason, the structure, depending on how badly racked, can be extremely unstable. The amount of racking can be determined from visible observation of the structure's corners. The further out of plumb and leaning they are, the worse the situation could be. The size-up of this type of structural situation should include visually checking the deformation of structural supporting members (columns and beams) and all connection points of any structural supporting elements. You may be able to suppress the racking by raker shoring the corners against the lean; place two rakers against the leaning corners on all sides if necessary (an operations- or technician-level skill).

Doors or windows out of rack

One very visible and easy way to check if the structure has moved or racked is to look at the windows and doors and assess how they are fitting into their

framework. Look at the amount of racking and determine which area is the worst. The building may have shifted uniformly, or certain areas or floors may be worse than others, presenting more problems structurally. You should be able to spot the racked openings as you approach the building from many feet away. Of course, the more visible the rack, the less stable the structure is.

Severe weather conditions

Always be aware of weather problems at an incident. If high winds start to develop, they can easily cause unstable or delicately balanced walls or floor sections to shift, causing secondary collapse. Heavy precipitation such as rain or snow can cause shifting of debris and unstable floors and walls. Always keep an eye on this situation; it will be a judgment call on the part of the incident commander if operations need to be postponed or stopped.

Missing or broken structural elements

Beams, columns, girders, and arches are all primary structural elements that support other structural elements. These elements must be checked as soon as possible. The building elements they had been supporting may be under substantial additional stresses, possibly ready to fail at any time. Shoring of these primary elements will resupport sections of floors that may be compromised. It is much easier to replace or restabilize one item than to erect several shores. Generally, these are the first items you should be looking at as you start the shoring size-up. Your team must be skilled in building construction identification to be able to quickly identify these particular structural supporting elements. (If they do not, have them take a class to improve their building construction knowledge.) Normally, the quickest way to safely resupport a damaged structure is to concentrate on these primary elements and properly identify what they are supporting.

Common Causes of Structural Collapse

Collapses are caused by many different factors, some obvious and expected, while others are freak accidents that cannot be anticipated. Ever since humans have been erecting buildings, these structures have been collapsing. The following sections describe several common causes of collapse and many that occur with regular frequency. Some of these can be prepared for, while others cannot.

Arch or column failure

Arches and columns generally give little or no warning before they fail, and they abruptly collapse. If any part of an arch fails or is removed, the entire arch will fail. The arch is the sum of all its parts, and it needs the support of all its parts to support the loads properly. As the arch fails, generally any overhead structural elements supported by that arch will also fail, which can lead to some serious collapse problems.

A column is any structural member under compression that is supporting a load from above. If a column supporting a beam joint or another column above fails, a structural collapse will occur. The results of arch and column failures are very similar, and as they fail, other structural elements will as well.

Collision impact

A collision impact can occur in any response district. For any number of reasons, an automobile, truck, or piece of heavy construction equipment can go out of control and hit a structure, which will often cause a collapse of the structure. These collapses, depending on the type of structure, can be localized and may not be too severe. The occupants of the vehicle can easily become trapped in the damaged vehicle, and if so, a compound problem will exist, a vehicle extrication in a collapse operation. Assess both situations. For the safety of the victims and rescue personnel, shore up and stabilize the structure before making any attempt to extricate the victims.

When the collapse is more extensive, the possibility exists that building occupants may be trapped simultaneously with victims pinned in the vehicle. Survey the remaining portion of the structure for stability, and

if necessary, shore it before trying to remove victims. This situation necessitates a two-pronged attack, which constitutes a difficult operation requiring extensive use of personnel and equipment and the coordination of both teams.

Explosions

Explosions are usually caused by the ignition of undetected leaks of natural or propane gas, which, when ignited, can demolish entire structures, resulting in extensive collapse, trapped victims, and numerous injuries. In an explosion, the structural elements of a building are subjected to tremendous stresses. Do not consider any part of the building still standing to be structurally stable until a thorough inspection for stability has been made. Extensive amounts of debris and demolished construction material will be found throughout the structure. Experience has shown that injuries caused by an explosion will be severe. Victims may be trapped anywhere in the debris, and the number of survivable voids may be limited.

Unfortunately, the United States is now subject to the same situations that have plagued Europe and the Middle East—terrorist bombings. The terrorist attacks of September 11, 2001, and the bombing of the federal building in Oklahoma City are two such incidents that have occurred in the last several years. These incidents become extreme mass causality operations caused by the massive damage of the bombs. These kinds of explosions have done tremendous structural damage over wide areas, and they can and have collapsed more than one building in the same incident.

Fire-weakened structural members

When a collapse occurs in a structure that previously suffered fire damage, all of the building's supporting elements should be suspect. The structural integrity of any construction materials exposed to the fire may not be reliable and must be closely examined. If any bearing members have been exposed to fire, then almost any type of collapse void may be created, since there is a lack of solid bearing. In addition, any sections of the building left standing must be thoroughly examined and must be shored up before any extended operations can take place.

Improper alterations or renovations

One of the most common causes of collapse in an urban environment consists of improper alterations or renovations. An alteration is defined as new construction within a building that may change the building's structural parts, mechanical equipment, or opening locations without increasing the structure's overall area or dimensions, or as a construction project comprising revisions within or to prescribed elements of an existing structure that is distinct from additions to the structure. A true renovation does not alter the structural elements of the building or their locations. It is more cosmetic in nature and generally not a hazard. (Many laypersons use the words *alterations* and *renovations* interchangeably; see chapter 2.) When inexperienced workers make illegal alterations, they may remove structural bearing members, such as columns or sections of bearing walls. The results can be catastrophic as well as deadly.

Natural disasters

Weather-related incidents, such as hurricanes, floods, mud slides, tornadoes, and so forth, have caused tremendous damage, as witnessed recently in Florida and California. These events cause extensive collapses, victim injuries, and extremely hazardous working conditions. The rescue teams must deal not only with the conditions of the collapse but also with the unpredictable conditions that the weather may bring. These additional problems, which must be anticipated, make the situation one of the toughest, most unpredictable, and most dangerous of all operations. The other major events are, of course, earthquakes, which can cause widespread destruction and occur several times a year. Earthquakes have caused massive loss of life, and many times it is next to impossible to get to heavily damaged areas. The infrastructure in the area may be completely destroyed, delaying relief sometimes for a substantial amount of time.

Tornadoes. The definition of a tornado is a violent, destructive whirlwind accompanied by a funnel-shaped cloud. Generally, tornadoes in the United States spin in a counterclockwise rotation and seldom exceed speeds of more than 300 mph. Most tornadoes occur in the Midwest from March through June. They usually approach from a southwesterly direction and do not last more than 30 to 45 minutes. However, some have gone on for more than three hours, leaving

several hundred miles of destruction in their wake. Not only will the winds do severe damage, but tornadoes have been known to lift extremely heavy objects and throw them several hundred feet. Tornadoes can also create major building collapses.

Hurricanes. These severe storms are created by low-pressure systems over the ocean, generally originating near the equator. Hurricanes create a large circular mass and have winds in excess of 150 mph. They generally do damage to coastal areas and lose intensity when they hit land. In the northern hemisphere, they rotate counterclockwise, and in the southern hemisphere, clockwise.

Earthquakes. As shown by some recent earthquakes, massive damage and structural collapse can occur. The amount and intensity of the damage will increase as the strength of the earthquake increases. Structural damage can be caused by faulting of the ground, both horizontally and vertically. Shaking is generally the most commonly experienced phenomenon when earthquakes hit. Closer to the fault center, the shaking is known as near field, and at much greater distances away, it is known as far field. Another consequence of an earthquake is liquefaction. When the drastic shaking occurs, the soils get temporarily transformed into a fluid mass and lose their supporting strength. Liquefaction occurs in loose deposits of fine sand and similar type areas. It can cause buildings to sink or lean over or both.

The biggest problem faced by rescue personnel after an earthquake is the constant threat of aftershocks. Numerous aftershocks occur after every earthquake. Although they diminish in intensity and frequency with time, this reshaking can and generally does cause even more damage to already damaged structures. Aftershocks are extremely dangerous to rescue personnel, because they can cause secondary, total collapse in buildings, thus trapping the rescuers.

High winds. The major cause of wind damage is the change in atmospheric pressure and the velocity of the wind. Wood-frame structures and lighter weight buildings are most likely to be affected by these conditions. Some of the more common results from high winds are roofs lifting off buildings, broken windows, thin lightweight walls peeling away from their framework, and falling chimneys, which can cause injuries or collapse of other structures.

Mud slides. Land, rock, and mud slides result in tremendous damage and casualties in a very short amount of time. Large boulders have been known to destroy anything in their path. While land and mud slides have been documented to move buildings hundreds of feet off their foundations, some are totally destroyed, while others may stay somewhat intact. The amount of damage depends on the size of the structure and the type of structural components of the building. Many times these massive events are triggered by earthquakes and torrential rainstorms.

Snow. In recent years the northeast section of the United States, especially New York, New Jersey, and Pennsylvania, has experienced much larger snowfalls than usual. The winters of 1996 and 2010–2011 set records for snowfall in southern New York. There were dozens of roof collapses in the tristate area, mainly because of the additional weight on the roofs of these structures due to the snow load. Heavy rains a few days after heavy snowstorms can create another common winter problem, causing drains to clog and adding weight to the already overtaxed roof members, perpetrating more roof collapses.

Floods. Water can also be a contributor to the causes of structural collapse. The two main types of flooding are river and coastal. The damage is caused by hydrostatic lateral pressure against a structure. Dynamic forces are also applied against walls and foundations by the water velocity (current) or wave action and the impact from waterborne debris.

Overloaded floors

Too much stock and heavy machinery and equipment are some of the more common reasons for floor failure. The additional weight applied to the floor tremendously stresses the beams. Even a slight impact load applied to the floor can cause beam failure, resulting in the victims being pinned under the stock or debris on the lower floors.

Overloaded roofs

Heating, ventilation, and air-conditioning (HVAC) units, large signs, and improper or blocked drainage ducts can contribute to excessive weight on a roof. Extensive roof beam failure will cause the roof and its contents to have an impact on the lower floors, possibly causing a collapse of the entire structure.

Security measures

In locations where security is a problem, the owners of commercial buildings may take extreme measures to protect their property, including the use of heavy gates on the face of the building, which places excessive weight and stress loads on the front wall's structural members. In some instances, these gates can pull down the entire front wall, causing extensive collapse damage. Another, more dangerous, security measure is the use of steel-plated roofs and, occasionally, walls. Plating adds tremendous weight to structures beyond what they were designed to bear. Very little additional loading is needed to cause the failure of these structures. Because of the crushing weight of the steel and the difficulty in removing debris, this type of collapse creates a very limited number of voids where survivors may be found.

Structural weakness

Although of major importance, structural weakness is one of the most difficult problems to detect. Most of the structural elements vital to the building's stability are hidden from view by interior coverings, lath and plaster, drywall, and so on. Exposure and neglect can cause a structure to age and deteriorate rapidly. Structures have a life span, just as humans do, and they are subject to the elements and use and abuse 24 hours a day, seven days a week, whether they are open or not. If they are not properly maintained, they can become fatigued and fail in any number of ways. A building that has suffered this kind of damage is extremely unstable. Major multifloor collapses have occurred when vertical support members have deteriorated and failed.

Wall failure

Supporting walls can fail for a number of reasons. Two of the most common are foundation failure and deterioration of masonry structural elements. In unframed structures, wall failure can cause extensive damage, if not total building failure. Large amounts of crushing debris are generated, and extensive search operations may have to be undertaken.

Safety Precautions

As with any other incident your department responds to, the safety of the rescuers and the victims is of paramount concern. Safety is everyone's concern, but when fire personnel are intensely involved in rescue operations, they have a tendency to put some safety factors on hold. They are concentrating on the rescue of trapped civilians, as they should be. But someone should be concentrating on the safety of the rescuers, which is where the chiefs and safety officers come in to play. Of course, finding the happy medium between rescue and safety can be a tough call in a serious building collapse. The following are some common things to pay attention to, though the list is not exhaustive.

Utilities

Immediately shut down all the utilities supplied to a building. These utilities generally include but are not limited to gas, electric, and water. The combination of these three can cause explosion, flash fire, and electrocution, drastically increasing the hazards to the victims as well as the rescuers. Eliminate these hazards as quickly as possible to ensure the safety of victims and rescue personnel.

Light

Most collapses involving buried victims are extended operations. During daylight hours, lighting may be needed, especially in extensive void search operations. During dusk and at night, illuminate the entire area for the safety of the operating personnel and for assistance in the search and rescue of trapped victims. The rescue team must have provisions already made for quickly setting up adequate lighting systems.

Personnel

Keep all nonessential personnel and rescue workers not immediately engaged in victim extrication or void exploration out of the collapse area to minimize debris shifting or the unauthorized removal of structural supporting elements. Loading up the structure with personnel also adds substantial additional weight that is not needed on top of an unstable debris pile.

Stability

Assign a safety officer to constantly monitor the stability of the adjoining buildings. A survey transit is extremely helpful in detecting any movement of unstable walls or floors. This instrument should be continuously staffed, and any movement communicated to the command post immediately.

If any substantial debris removal is to be initiated, the operations officer must continually evaluate whether to shore up or demolish specific areas of the collapsed building. The two major factors involved in determining whether to shore up or demolish are the safety of operating personnel and the possibility that there may be trapped victims. If the slightest doubt exists as to whether any part of the structure is stable, the safest thing to do is to shore it up. When in doubt, shore it up!

Danger zone

Establish a collapse danger zone around the structure in question. The danger zone should be greater than the height of any of the walls still standing. All equipment, apparatus, and additional personnel should be kept outside of this danger zone. Remember, the safety of operating personnel is a priority; you do not need the rescuers to become victims.

Teamwork

Have members work in teams under close supervision, and make sure all work is properly coordinated among the separate teams. This is done so that more work is not created for the rescuers. Proper coordination of debris disposal is necessary to conserve time and energy. Ideally, collapse debris rubble should be handled only once. Relieve rescue personnel continually, according to the amount of debris handled and weather conditions. Relief periods as short as 20 minutes or as long as 40 minutes can work well. The command chiefs and line officers must maintain strict control of their personnel, and this is probably one of the most difficult tasks to perform at a collapse operation. The firefighter's inherent aggression and quick actions could be a problem at a collapse operation, which must be handled methodically and safely. Members operating alone and out of sync with rescue teams are unsafe and counterproductive. Collapse situations are the most unpredictable and dangerous

scenarios that firefighters will encounter. Discipline must be maintained if the operation is to have a safe and successful conclusion.

Air quality

Depending on the type of operation and depth of confinement, self-contained breathing apparatus (SCBA) may be necessary. If any smoke or airborne dust is present, the use of masks, even though they may be cumbersome, may be warranted. If necessary, insert hoses into the debris piles to gently feed fresh air to trapped victims. If an extensive tunneling operation in a basement or subbasement is needed, confined space operations may have to be instituted.

Begin immediately to constantly monitor all gases; take readings until collapse operations have been concluded. A hazardous response unit should be especially called for this purpose and in cases where dangerous chemicals are encountered and have to be removed. Do not attempt to handle the chemicals yourself. Wait for the hazmat unit.

When operating in void search operations, check the oxygen level before entering any void. If it is below 19.5% or above 21.5%, take the appropriate action. Continually monitor the carbon monoxide level. The use of an explosive meter is also warranted; pockets of residual gas from broken lines may also be present. Gases that are heavier than air may collect in lower void spaces and pose a threat to rescuers who are not properly protected.

Vibration

Avoid any unnecessary shocks and vibrations. Have any subway or rail traffic in the immediate vicinity halted for the duration of the rescue operation. Limit the use of loud machinery or equipment, and keep compressors and generators a safe distance from operating forces. Keep the use of gas power tools to a minimum. If any part of the structure is unstable, the vibration of all types of tools, especially the gas-powered ones, can post a risk of potential contamination of the atmosphere.

Emergency signaling

Effective emergency signaling and evacuation procedures are essential for the safe operation of all personnel at a disaster site. The signals must be clear and understood by *all* involved in the rescue effort. Make sure that everyone who is involved in the rescue or recovery effort is aware of and understands all the signals. Civilians, including engineers, construction workers, police officers, equipment operators, and the like, are not aware of these signals. Air horns are the most common device used for these signals. They can be portable or apparatus mounted.

Figure 1-6 shows the three most commonly accepted emergency signals for a collapse operation. They are accepted internationally and by the Federal Emergency Management Agency Urban Search-and-Rescue (FEMA US&R) system. It is best if you can stop operations just before you have to evacuate the structure. This may not be possible in some situations with immediate danger; each situation will determine the sequence. Ideally, with all the noise going on in a typical collapse rescue operation (if there is such a thing), having everyone stop for a moment to listen really pays off. It keeps things a bit more organized and safe. Sound one long blast on the air horn, letting everyone know to stop operations and shut their tools down. Anticipate an evacuation to occur next, using a previously established exit route.

The second signal illustrated in figure 1-6 means stop everything and evacuate the area to the designated safe haven or safe zone outside the structure. When this signal is activated, do not stop to figure out what is going on or where the problem is located—that would only be wasting time. Evacuate immediately but prudently—*do not run*, or you may trip and fall and possibly injure yourself or someone else.

After the situation that caused the evacuation has been addressed and taken care of, it is time to return to work. The one long and one short blast means return to your duties.

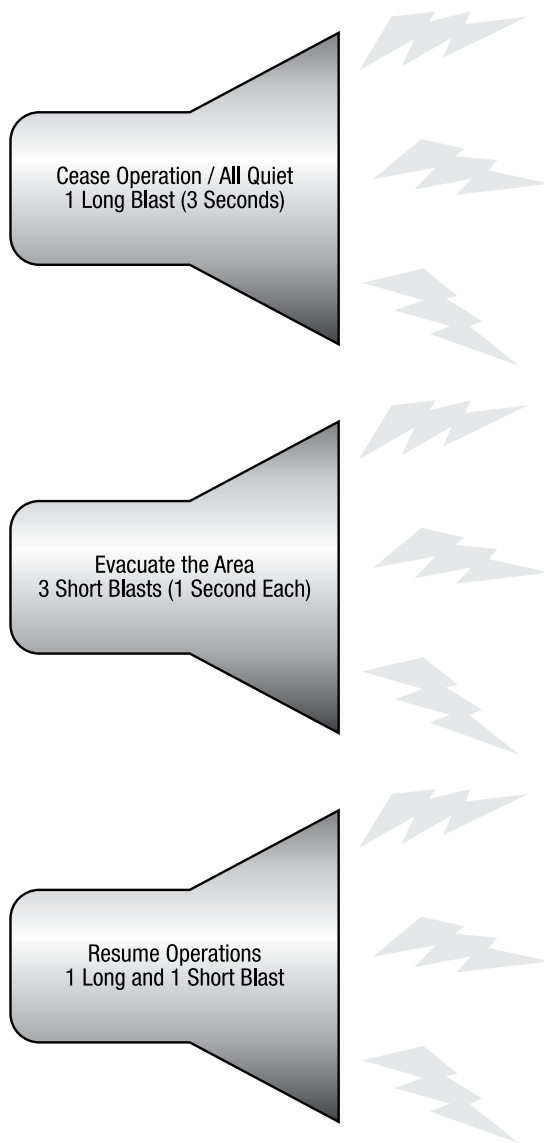


Fig. 1-6. The three most commonly accepted emergency signals for a collapse operation

Building search marking systems

A system has been developed and used by many FEMA and international teams that will work well in any locality in the country. The following sections describe each facet of the search marking system.

Structure and hazard evaluation marking.

After making an assessment of the building or remains of the building, you need to report the results. This should also be done with any adjoining structures affected by the collapse. In a one-building collapse

incident, you would inform all personnel of the results. It generally would not be necessary to place a box on the remains of the building, unless there are several mutual aid units arriving at a later time. When more than one structure is affected, then you would place the marking box on the other structures. Each box should be approximately 2 feet by 2 feet, and orange paint is used for the markings to make them visible from the street (fig. 1-7).

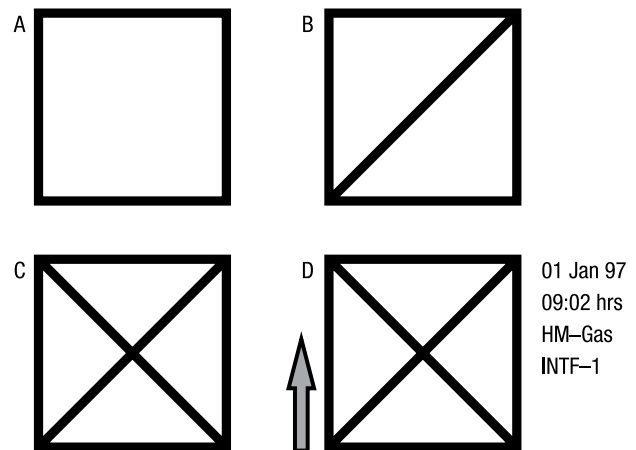


Fig. 1-7. Structure and hazard evaluation marking

Figure 1-7A indicates a low-risk building. You can conduct rescue operations without having to do extensive mitigation or shoring. This does not, however, mean that there is no danger. Always keep an eye on your surroundings at all times. Remember, any time you remove anything from the area of the building, you change the equilibrium in that area. You must determine what will shift or move whenever you remove any substantial item from an area of the structure. In Figure 1-7B, the building is considered a moderate risk. It has significant structural damage. Some areas may be at minimum risk, while others may need removal of hazards, monitoring of unstable areas, or shoring and bracing before search and rescue operations can be conducted. Figure 1-7C shows a high-risk building. The entire structure or major parts of it are very unstable, and secondary collapses are a significant risk. Substantial mitigation or large and possibly complicated shoring operations will need to be conducted before attempting any rescue operations. These operations will most likely be time consuming and will need significant resources, such as large machinery, lumber, heavy-duty tools, and the like.

As you assess the structure, identify the best way into the building, as shown in figure 1-7D. This would normally be done with an arrow directed to the best and safest entrance to the structure. Put the time and date the assessment was completed. This is especially important for incoming mutual aid units, so they will know how long ago your team assessed the structure. Identify who did the assessment and also point out any hazardous situations in the marked area.

Search and rescue marking. Often when you are the first-arriving units and just starting rescue operations, the marking system is not the first thing on your mind. As your personnel enter and start search operations, the company officer should pick a visible spot near where you entered to place the first mark. It will be a reference for everyone as the operation continues. If the operation becomes prolonged, and mutual aid companies respond and begin work at the incident, it will be prudent to have marked all the areas your teams have searched, to avoid duplication of the searches in the initial stages of the rescue. Before operations are concluded, a secondary search of all areas needs to be accomplished before the all-clear signal is given.

When the void search team members first enter a structure, they should place a single diagonal slash approximately 2 feet long at the entrance to the area, using orange or red paint for high visibility. The use of spray cans is the norm; they are generally the easiest to work with and are disposable. This mark indicates to other teams that initial search operations are underway. After the search team personnel have left the void area and completed their search, they would place another diagonal slash 2 feet long at opposite angles to the previous one, creating an X pattern. This denotes to other rescue teams that the immediate area inside has been searched.

Figure 1-8 shows the proper way to mark the search area. The left side of the X is where the search team identifies itself while it is conducting search and rescue operations. Place one diagonal line near the entrance, and place your team's identification and the date and time you entered the void area. This will tell all operating personnel that an ongoing search operation is being conducted in this area. The top of the X will be marked with the month, date, and year and the military time when the search has been completed and your teams have left the void. The right side of the X will include any pertinent information on the hazards that your personnel may encounter: utility hazards,

such as open waste pipes, heavy water conditions, live electrical, broken glass, drop ceiling or hanging electrical wires, or rodent and vermin problems such as rats. The bottom of the X will contain the results on confirmed victims in the searched area. The number of live and dead victims should be placed in the X. If your search comes up negative, then a zero (0) is placed in the box. After the victims have been removed, put a line through the number and write the time and date when they were removed. Since you will be operating with your first-due personnel and your own rescue teams, you can skip some of the less pertinent information that would be needed by other rescue agencies that would be responding in a day or so. If this will be a single-day operation, then your search marking system could easily look like this illustration. Your teams searched the day of the incident, and if anyone was rescued or removed, put that number at the bottom of the X and mark the time and date.

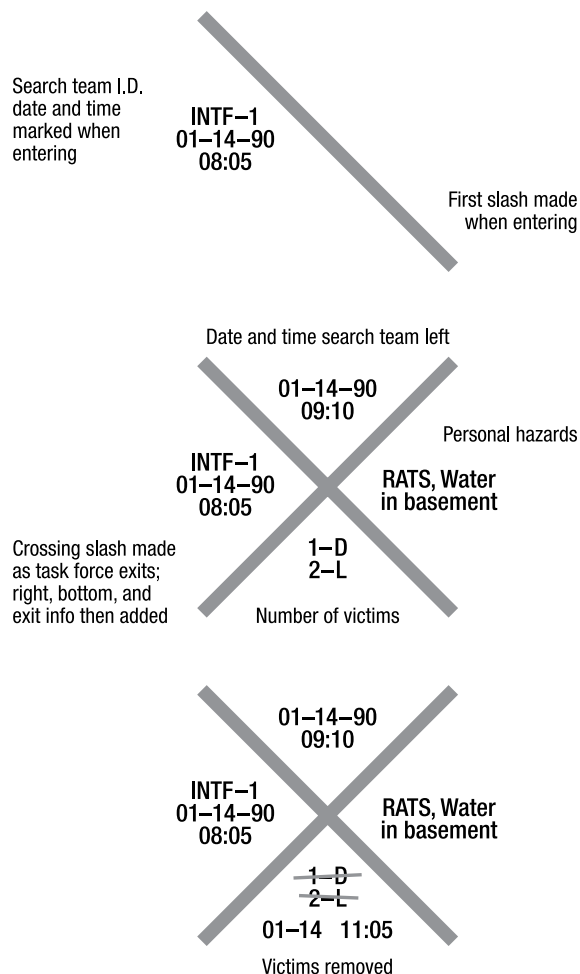


Fig. 1-8. Search marking systems

Upon entering, the searcher(s) should proceed if possible in a consistent pattern in order to ensure that all areas are searched. “Go to the right, and always keep to the right in every room” is a common method, but “go left, stay left” is also used. However, in heavily damaged and collapsed areas, this technique might be impractical. There might be too much debris, furniture, partition sections, and the like. One way to keep the search organized is to use the entrance as the orientation point. Go left or right from there as far as possible, and search the voids where you can. After each area is searched, return to the entrance point. At this time, move right or left (following the direction you have decided to search) to the next void, using the entrance as the point of reference. In this way, your team leader will know which sections from the face of the void have been searched. Be consistent and search all areas, and notify the team leader whenever each area has been examined.

Unfinished search assessment marking. Figure 1–9 shows how to mark the area to indicate that an incomplete search was performed. The incomplete search mark here shows that Rescue 2 entered at 11:00 hours and left at 14:20 hours and searched the first and second floors and the front half of the third floor. The rest of the structure has not been searched yet, as indicated by the circle in the middle of the slash mark. Box A is an example of a section or sections of the building that the team *did* search. The example in box B states that Rescue 2 did a totally exterior visual and audible search of the structure but did not enter the building.

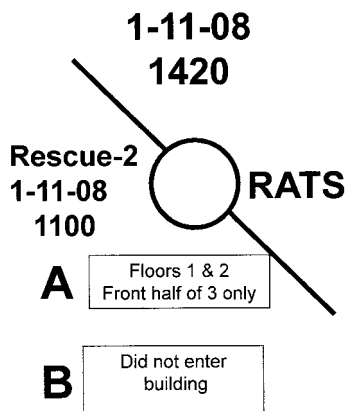


Fig. 1–9. Unfinished search assessment marking

The rescuers may have entered the structure and only searched some of the floors or floor areas, or the search may have been of the exterior only. The extent of the search should be indicated by the information in the box below the search mark, as shown in figure 1–9. If you did not complete the entire search, place a circle in the middle of the slash.

Victim location marking. This series of marks is used to indicate the location of each victim discovered on the rescue site. The victim location marks are normally made with orange spray paint, a paint stick, or a carpenter’s crayon. During the primary search operations, your personnel may have seen or heard something that could indicate a potential victim. If this is the case and you cannot immediately access the area, mark it with a large V (see fig. 1–10). The V should be roughly 2 feet high, to be visible from outside the immediate area, and located as near to the victim as practicable (fig. 1–10A). It could be placed on a nearby wall surface or directly on a piece of rubble. This is not always easy to do given that there may be only rubble that has to be removed in the area, making a close marking impractical. An arrow may have to be added to indicate the exact victim location. At the top, your team should identify who found the victim, especially if more than one rescue agency is operating. Add a circle around the V when the victim has been positively confirmed and is still alive (fig. 1–10B). The initial V could be placed when the victim has been located, and the circle added when the fact that the victim is alive has been confirmed by another rescuer, a search tool, or positive visual evidence. When the victim has been removed, place a large X completely through the circle, indicating that removal has been accomplished (fig. 1–10C). A horizontal line is added through the V if after examination the victim is confirmed to be deceased (fig. 1–10D). If your response to the scene is limited, and you do not have enough personnel to conduct large-scale operations, it may be necessary to leave deceased victims in position until later. The rescue of live victims must take precedent over deceased ones. Mark this area for operations later, after all confirmed live victims have been accounted for.

This will identify the spot where a more organized rescue can be done with additional personnel and specialized tools, if necessary. These marks are generally made after a search has been performed, unless the victim was immediately removed. If the victim was removed, have the victim-tracking officer (a safety officer can do this job) document the location.

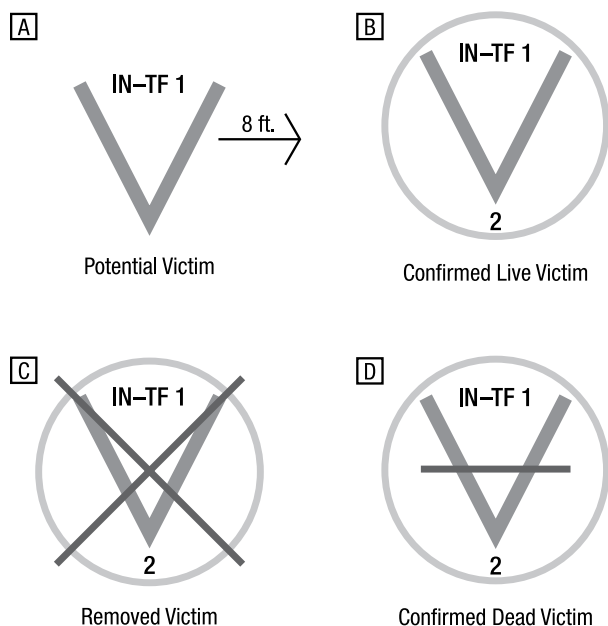


Fig. 1-10. Victim location marking

Figure 1-11 shows the marking systems used in a major gas explosion that occurred in Puerto Rico. The task force identification is on the left side of the search marking, and the bottom has the victim count 0, indicating no victims in this store. On the top are two markings, the first for the primary search and the second for the conclusion of the secondary and final search. The square box is the structure hazard evaluation, and the empty box means that operations can be conducted in this area without major shoring or debris removal.



Fig. 1-11. Victim location marking for a major gas explosion in Puerto Rico

Safety Planning

Potential collapse incident risks and hazards

From the very beginning of an event until the very end, rescue personnel conducting search and rescue operations may be exposed to numerous potential risks and hazards including but not limited to damaged infrastructure; secondary collapse from aftershock, vibration, or gravity; fire; and explosions.

Unfamiliar surroundings. When entering an unfamiliar structure, operations can become impeded. When that structure is collapsed as well, the problem is compounded. As a result, you must slow down operations until proper evaluations of structural stability, utility, and hazmat issues have been done.

Unstable structures. Proper size-up and evaluation of any building you enter is essential, regardless how little damage you notice. Secondary collapse from unstable remains of structures is the major cause of serious injury to rescue personnel.

Falling or tripping hazards. Always examine each area you enter, as well as surrounding areas, for potential instability problems, especially when climbing or walking on collapsed debris and rubble.

Falling material or flying objects. In multistory structures or where exterior walls are still standing, regardless of building height, constantly be aware of any items coming loose or sections of unstable walls starting to fail.

Exposure to hazmat. One of the first things your team must do is determine the type of occupancy of the building, especially the potential for hazardous materials affecting your rescuers.

Decontamination. If any of the rescuers are inadvertently exposed to some sort of agent or chemical, they will have to be decontaminated on the scene to prevent further exposure to themselves as well as others.

Exposure to smoke, dust, and the like. Although not as potentially serious as a hazmat exposure, rescuers must be protected from airborne agents that can cause respiratory problems. The proper mask for the amount of exposure should be used at all times.

Fire and explosion. At most collapses, there is a risk of fire or explosion. Always stretch and charge a line regardless of whether you see any fire.

Excessive noise. Whenever operations require the use of tools and equipment, there will be noise. With personnel talking and using radios and equipment being used, especially gasoline-powered saws and generators, there will be a lot of noise as well as vibrations. Communication becomes difficult because of the sheer volume of noise being generated.

Electrical hazards. Almost any building collapse has the potential for live electricity in the collapsed debris. The rescuers need to make sure that the utilities to the structure have been terminated well before entering the building.

Confined space operations. Although a structural collapse is not a confined space incident, in some instances this is a concern. For example in a basement or subbasement with very limited access, some confined space procedures could be used as a safety precaution.

Oxygen-deficient atmospheres. Even though it happens rarely in a collapse, loss of oxygen is still a risk. The team should always check the atmosphere when they go below grade or into a deep void just to be sure. Bring a 5-gas meter in with you.

Contaminated air and water. In any collapse situation, be aware that the water and air may become contaminated from numerous sources within and outside the area. Check both for possible hazards.

Electrocution from damaged utilities. In the initial stages of the collapse incident, before utilities have been confirmed as shut down, electrocution is a very real possibility. Touching the wrong thing can be extremely dangerous, especially if there is water leaking throughout the collapse area. Avoid all electrical appliances and cables until you know for sure that the power has been shut down.

Dangerous equipment. Operating in and around areas with extraction or construction equipment always presents a potential for injury. Safety personnel must be stationed in these areas to coordinate personnel movement with all equipment.

Fitness for duty. Rescuers must be in good physical condition to be able to perform their rescue functions.

Excessive fatigue and sleep deprivation. Rescuers who have been working long hours and are

physically exhausted might make poor decisions and get hurt.

Adverse weather. Extreme heat or cold or inclement weather can impede the rescuer efforts as well as quickly debilitate personnel.

Stress. Keep an eye on all rescue personnel during an incident. If you notice someone who is very agitated or extremely “stressed out,” send that person back to the staging area for rest and evaluation.

Security. The safety of rescue personnel and their equipment is a major concern. Security must be provided at every incident. Well-meaning but untrained civilians can create major problems, and they must be kept out of the site for their safety as well as that of operating firefighters.

Safety equipment. Make sure that all rescuers have the proper personal protective equipment (PPE) where necessary. Also identify any special safety equipment that may be necessary during the operation.

Escape routes. Always make sure that rescue personnel have an easily accessible way out of any area where they are operating. In case of secondary collapse, all rescuers must know the specific route to exit the structure. It is the safety officer’s job to identify, mark, and inform the operating personnel of the escape route.

Safety zones. Establish safety zones as soon as practicable, ideally in the first 15 minutes of the rescue operation. Determine the immediate rescue area, the most dangerous “hot zone,” and the safe area.

Safety plan (LCES)

The acronym LCES stands for lookouts, communication, escape routes, and safe zones. In any operation these factors need to be addressed to ensure the safety and accountability of all rescue personnel at the incident. If it is necessary to make changes in the safety plan, all team members must be informed of the changes. Changes affecting the entire operation should be communicated up the chain of command immediately; those that are site specific can be passed on to the appropriate rescue team.

The safety plan needs to identify the signals for immediate evacuation, cease operations, and resume operations. It will also need to designate a safe area that will be used as the staging area in case of emergency evacuation. A multihazard safety plan is a guide to the

basic elements of safety for a variety of incidents. The components of LCES safety planning are described in the following sections.

Lookouts. This is normally the function of the designated safety officer, which should be a specific position without additional operational responsibilities. Safety officers need to concentrate on the safety of all operational personnel and potential victims under their jurisdiction. They need to be free to watch over the entire operation, identifying potentially dangerous situations and addressing them before they become a problem. A second safety officer may be assigned to a single location to monitor a special hazard. Safety officers need to pass along any necessary information to anyone relieving them during a long operation.

Safety officers or lookouts work from a position of safety and clear visual access just outside of the direct work area. They should not become involved with the actual hands-on part of the operation. They should be readily identifiable to all, by their radio designation and by wearing an identifying vest. Team members tasked with this responsibility must resist the temptation to become involved in the tactical operations. The success of the mission depends on the ability to identify and address hazards before they become problems.

Communication. A communication plan should identify the command, operational, and special radio channels where applicable and available at the time of the incident. These are the operations personnel's contact to the outside for resources, support, and safety. During the safety briefing, before beginning to work, identify the specific methods of signaling that will be used at the rescue site should a problem arise. For example, placing two radios together, speaker to microphone, and pressing the transmit buttons creates a loud tone that will be heard on all other radios tuned to that frequency. In addition, air horns, car horns, whistles, a personal alert safety system (PASS) device, and clear text over the radio are all methods for signaling.

Escape routes. An escape route needs to be a preestablished and identified path to an area of safety. The safest method of exiting an area may not always be the most direct route. The most direct route might go right through the collapse path of the remains of the building. One option is to have rescuers remain in place. If the working area has been examined and stabilized, and leaving this area would expose the

rescuers to a variety of hazards, then the safest thing may be for them to stay put.

The rescue situation is often dynamic. Changes may occur as a result of external forces or because of a rescuer's action. The escape plan needs to be continually updated and adjusted to reflect changes in the rescue situation. As a new plan is developed, all rescuers affected must be made aware of the changes. An acknowledgment of understanding must also be received from each team member to ensure everyone understands the change.

Safe zones. Safe zones, also called safe havens, are preestablished areas of safe refuge away from any potential hazards. These could be specifically designated areas outside the hot zone or agreed-upon safe areas within the hot zone. If the safe zone is within the hot area, rescuers may have to construct or shore up a safe area around themselves and any victims near them. Part of the safety plan should provide for a designated safe zone where a team roll call is taken. This count should be immediately communicated to the next person in the chain of command to provide 100% accountability of all personnel.

Rapid Intervention Team

Much has already been written on rapid intervention team (RIT) operations, and your department no doubt has RIT procedures and standard operating procedures (SOPs) already in place. The following are some things your team should be thinking about in addition to your regular RIT SOPs when faced with a potential collapse incident. You may need additional equipment, which should be planned ahead of time. When involved in a technical rescue incident, such as building collapse, all RIT members *must* be trained for all facets of structural building collapse, not just for their specific assignments. The firefighters need to be familiar with building construction, void search operations, shoring, cribbing, rope and confined space operations, and the proper use of almost all tools used in construction, just to name a few.

Standard operating procedures. Although the RIT members will already have SOPs for rescuing downed firefighters in a fire scenario, they will also need specific SOPs for technical rescue situations. In building collapse situations, there may be times

when special operational skills will be needed for specific collapse operations (such as void search and rescue techniques and shoring). Procedures for implementing these operations need to be identified *before* your team responds to collapse rescue situations.

Personnel. Although some standards say that as few as two personnel can constitute a RIT, in a technical rescue incident that number would be seriously deficient and dangerous. In a structural collapse rescue operation, where a secondary collapse (or other situation) has trapped or injured responding firefighters, the RIT should have five or six collapse-rescue-trained personnel. This group should also be capable of being broken down to two smaller teams if necessary. They may have to enter a void from two different directions, or one group may have to do shoring or cribbing while the other is making the rescue.

Tool needs. In addition to the usual tool complement, the RIT needs additional extrication and cutting equipment for technical rescues. Battery-operated tools work well if the batteries have been properly charged and the RIT takes spare batteries to incidents. At least three reciprocating saws should be available to the team. One saw could have a wood-cutting blade, and the other two should have metal-cutting blades. Metal-cutting blades will cut wood, but not the other way around. A portable hand-operated spreading tool is also recommended, along with some smaller air bags, such as 6 × 6, 6 × 12, 10 × 10, and 12 × 12 (all in inches). These are used to move building material that may be pinning a trapped firefighter. The smaller, more maneuverable bags are ideal for void rescue situations.

Each person on the team needs to have (at a minimum) a knife, wire cutters, webbing, a personal rope with hardware, a good working flashlight, a prying tool (Halligan, pry axe), and a radio. No one on a RIT should ever go anywhere without tools.

Other tools that may be needed, depending on the specific situation, are bolt cutters, thermal-imaging equipment, atmosphere-monitoring equipment, acoustical listening devices, hot stick voltage detectors, small hydraulic jacks for lifting items off personnel, and perhaps initial stabilization equipment such as cribbing or small Paratech® struts.

2

Basic Building Construction Related to Building Failure

Introduction

Some of the most dangerous situations firefighters will encounter are unstable collapsed buildings. It is very hard to predict what will happen in these buildings because there is very little, if any, warning of an impending secondary collapse. This extreme unpredictability is why it is such a dangerous situation. Thorough knowledge of building construction is essential for any rescuer who will be responding to a structural collapse incident.

The purpose of this chapter is to familiarize the rescue firefighter with the standard construction practices and principles used by the construction and building industry today. What follows is by no means a complete list, but just some of the fundamentals that rescuers should learn well and train with so that they can understand the basic physics of structural engineering. Once they understand how and why structures stay up, rescue firefighters can more easily determine whether to enter a structure. They will be able to judge with some confidence the amount of instability of the remains of the building. Knowing how stable the existing building is will help you to decide whether to start interior rescue operations, void-search procedures, or debris-removal operations.

Knowing how a building is erected and basic load support principles will make it much easier for rescue shoring personnel to install shoring if necessary. The paramount concern of the rescue shoring team is to stabilize and resupport the primary elements of a damaged structure. The sooner this is accomplished, the safer it will be for all personnel operating in the building and around the collapse zone.

Building Functions

The purpose of any building is to perform a function. The primary function of most buildings is to protect people from the weather by creating enclosed but interconnecting spaces. These spaces may be many and small, such as in an apartment house, or fewer and bigger rooms, as in a house, or a single space, like

a church or sports arena. The function of the building is fulfilled by the construction of its surfaces, such as the walls and the roof, which separate the outside from the inside. The structural components of a building ensure that the elements required to fulfill its function will stand up properly. Columns, arches, beams, and floors are the structural elements that make the architectural function possible. In years past, structures were erected by the not necessarily accurate but time-honored method of trial and error. Each builder would dare a little more than the previous builder until faced with some sort of structural failure. The pyramid at Meidum in Egypt has 250,000 tons of limestone lying around its base on all four sides, due to the most common cause of collapse, improper foundation construction. This is a basic building concern, even to this day. Although today's engineers have become a bit more sophisticated, collapses due to design and fabrication errors still occur on a regular basis.

Construction Principles

All buildings are erected from the ground up. As they are built, they are constantly defying the ever-present force of gravity. When erected, all buildings are constantly and continually fighting against being pulled to the ground by the forces of gravity. Every structure ever erected will be under this force for the entire time it will stand, whether for one year or for one thousand years.

All structures are built with this principle in mind. All loads generated within a structure or received from any source outside the structure must be transmitted. These loads must be transferred from the point they are received to the earth without any discontinuity in the load transfer to its structural elements. If there is any break in continuity, or if the structural foundation yields to any tension, compression, or shear forces, the structure will fail. This is the basis of load transfer principles in all building construction. By understanding this principle, we can determine the load transference and determine if there is a problem.

All loads must be transmitted to the ground. Generally, most loads are designed to be applied to the buildings floors. All parts, items, and structural elements of the building must be supported by something strong enough to handle the load from above. This can be a structural supporting element,

beams, columns, arches, bearing wall, girders, or *solid ground*, or any combination of all of these. Disconnect of any one of these elements will result in a collapse situation developing. Any load on a structure must be supported right down to the earth; the structural support must be continuous.

Almost all interior live, dead, static, or dynamic loads are applied to the building floors; every building is designed with this in mind. As a result, all floor joists in a building will act as beams, transferring the load at right angles to other structural supporting elements. The most common load transfers are from the floor beams to some sort of bearing element or combination of elements. The amount of support force needed will depend on the distance from the load the support point. This can be mathematically calculated, and it is generally less the further away the load is.

The structural floor elements, girders, beams, and joists are designed to act as beams. When a load is placed on the floor boards between joists, the floor boards deflect and transmit the load to the two joists on either side of that load. The load is then transmitted by the joists to either a girder, bearing wall, column, arch, or any combination thereof. The proportion of the load delivered to each support point depends on the relative distance from which point the load is applied toward each end. The load received by a bearing wall is delivered directly to the foundation and thus to the ground. The load that is received by a girder is divided among bearing walls and any intermediate columns, arches, or interior bearing partitions.

Basic Construction Definitions

Alteration

The two terms *alteration* and *renovation* are very different. They are sometimes used incorrectly. Basically, any change to the structure size, shape, or structural elements is an alteration. The key point is that it does not increase the overall area or dimension of the building. For example, changing the front door and making the door openings bigger, putting in larger windows, increasing or decreasing the size of the window openings, and moving interior walls are all examples of alterations.

Renovation

A true renovation does not alter the structural elements of the building or their locations. It is usually just cosmetic in nature and for our purposes is not generally a hazard. Many times an eyewitness will call an alteration a renovation, but they are not synonymous. On scene, the rescue team must determine this for itself. Replacement of interior or exterior coatings, upgraded plumbing, drop ceilings, new paint, and wallpaper would all be considered renovations.

Engineered construction

Quality-controlled construction techniques and practices are often referred to as engineered construction. This entails continual testing of all materials and fabrication techniques and is done until construction of the building is complete. This is usually done on larger structures, for public, commercial, governmental, retail, and public assembly uses. It is rarely done on private homes.

Vernacular construction

Vernacular construction is typically used for new home construction and old home renovations, including condominiums and townhouses. These buildings may be more dangerous from a fire and rescue standpoint, however, due to lack of inspections and the result of poor workmanship.

Stress

As it concerns structural building elements, stress is defined as the internal forces applied at a given point in an elastic material by the action of external forces. All structures deform whenever loads are applied to them. Although these deformations can seldom be seen by the naked eye, the corresponding stresses have measurable values. These stress patterns can be complex; however, most consist of the three basic states of stress: compression, tension, and shear.

Strain

The engineering definition of strain is a change in the form or shape of a body or material that has been subjected to the application of external forces as a result of stress. There is a big difference between stress

and strain, and it is imperative in a collapse situation to determine which is present. In the field the terms *stress* and *strain* are often confused and interchanged, but we must be able to recognize the difference quickly.

If a load is placed on an element and it deflects, this is stress. When that load is released from the element, and the element does not return to its original shape, that is strain. When strain occurs in a structural element, there has been a failure of that element on a molecular level. The element has lost its strength and can possibly fail.

Deflection

All structural elements deflect under a load, some very slightly and others with visual effect. Structural elements are designed to support loads without signs of visual deflection. Any visible sign of deflection indicates an overload and a potential problem or collapse situation developing.

If you notice deflection of a column, beam, or wall, report it at once, because this condition indicates structural overload.

Elasticity

The capability of a stressed body to recover its original size and shape after deformation by applied loads is elasticity. Strength is not the only property required of all structural elements. Generally, loads act on a structure either permanently, intermittently, or only for a brief period of time. All structural elements will deflect under load. The lengthening and shortening of a building's structural elements must not go on indefinitely and must disappear when the action of those loads ends. Strength guarantees that the material will not stretch or shorten so much that it will eventually break under those working loads. Elasticity ensures that the material and the structure will return to its original shape when unloaded. A material whose change in shape vanishes rapidly when the loads on it disappear is said to behave elastically. All structural materials must be elastic to a certain extent, although none of them can maintain elasticity indefinitely or under very high loads. Most structural materials show some form of deformation that increases in proportion to the size of the load being applied to them.

Elastic limit

The greatest amount of stress that a material is capable of sustaining without any permanent deformation upon complete release of that stress is its elastic limit.

Plasticity

In theory, all structural materials will behave elastically if the loads applied to them are kept within given limited values. When the load force goes above these values, the materials develop deformations. If these deformations do not disappear when the materials cease being loaded, this is called permanent or residual deformation. When this happens, the material has reached its plastic limit, and it is said to behave plastically. If these loads keep increasing after the appearance of plastic behavior, the material will soon fail.

Primary structural elements

Structural elements that support other structural elements in the same building are primary structural elements. These could be bearing walls, arches, columns, girders, or beams. The failure of one of these elements will cause the failure of any items this structural member supports. The failure can be local or catastrophic, depending on the location in the building. One of the primary tasks in a structural survey is to identify all the primary structural elements in the building and determine if there is a problem with any of them.

Load transmission

All loads that are generated within a structure or received from any source outside the structure must be transmitted from the point received to the earth. This must occur without any discontinuity in the load transference to its structural supporting elements. If there is any break in the continuity or if the structure's foundation yields to any compression or shear forces, the structure will fail. That is the basis of all building construction load transfer principles. By understanding this principle, we can determine by looking at the load transference if there is a problem. All loads must be transferred to the ground; given that most loads are applied to the building's floors, these struc-

tural floor elements will generally act as beams. These building loads are transmitted by the beams to girders, bearing walls, columns, or arches, or any combination thereof.

Load transfer

Basically, every load or structural element must be held up from the earth. This can be done either by the load itself or with another structural member strong enough to support it. The load must eventually bear directly to the ground no matter how tall the building will be. All parts, items, and structural elements of the building *must* be supported by something strong enough to handle the load from above. This can be a structural supporting element, beams, columns, arches, bearing walls, girders, solid ground, or any combination of all of them, which is the most common. If *any* of these elements disconnects, a collapse situation will develop. Any load on a structure must be continuously supported right down to the earth.

All interior live, dead, static, or dynamic loads must be applied to the building floors. This is a principle that is fundamental to the design of every building. Thus, all floor joists in a building will act as beams, transferring the load at right angles to other structural supporting elements. The most common load transfers are from the floor beams to some sort of bearing element or combination of elements. The amount of support force needed depends on the distance from the load to the support point. The proportion of the load delivered to each support point depends on the distance from the point to the load on each end. This can be mathematically calculated, and it is generally less the further away the load is.

Deflection

All structural elements deflect under a load, some very slightly and others with visual effect. Structural elements are designed to support loads without signs of visual deflection. Any visible sign of deflection indicates an overload and a potential problem or collapse situation developing.

If you notice the deflection of a column, beam, or wall, report it at once, because this condition indicates structural overload.

General Construction Types

There are five general types of building construction that firefighters normally encounter. These are categorized in the following sections by the most fireproof first to the least fireproof last.

Type I: fire-resistive

Type I structural members are made of noncombustible materials that have a specified fire-resistance rating. These ratings are based on the Uniform Building Code and National Fire Protection Association (NFPA) Standard 220. The fire-resistive classification is further broken down into subclassifications that reflect the hour ratings for each of the primary structural members. Generally, this hour rating for load-bearing members is 3–4 hours and 1½–2 hours for the actual roof material. Floor material is rated 2–3 hours.

The primary identifying factors are usually the main structural members. Steel and reinforced concrete are the most common types of building materials used. Even though steel is noncombustible, it rapidly loses strength when attacked by a heavy fire load. For structural steel to be considered fire-resistive construction, it must have an insulation material of some type, which is generally a sprayed-on coating. Concrete is also a noncombustible material with excellent insulating properties, but to be considered fire-resistive, it needs to be constructed with steel-reinforcing bar.

Type II: noncombustible

Type II structural members are fabricated from a noncombustible material but have no fire-resistance rating. The use of unprotected steel is the most common defining characteristic of a Type II building. Other noncombustible materials besides concrete and steel are also used, for example, concrete block (cinder block) exterior walls with unprotected steel beams or trusses for roof support. Steel beams and columns are also used to support the load of the building with block non-load-bearing exterior walls or a sheet steel metal exterior wall attached to columns. A one-hour fire rating is typical.

Type III: ordinary

The term *ordinary construction* covers a wide range of buildings. Its most common defining feature is that the exterior load-bearing walls are of masonry construction, and some or all other structural components, interior or exterior, are combustible—generally wood. The masonry walls of Type III construction can be of various types: brick, stone, concrete block, terra cotta tile, adobe, or even cast-in-place concrete. Inside the structure the floors, ceiling joists, and trusses are generally all made of wood. When we think of ordinary construction, we think of the old brick buildings seen in every city and town, but modern-day use of this type of construction is also evident in every area. The local fast-food place is probably constructed of concrete block load-bearing walls with a wood truss roof. This is typical Type III ordinary construction.

Type IV: heavy timber

Also called mill construction, Type IV buildings are basically the same construction as ordinary Type III, except that the wood beams and columns are far greater in size. These columns and beams are usually 8 inches (or more) thick, but in no case is the least dimension less than 6 inches. The floors are generally also made of hardwood.

Type V: wood frame

In Type V buildings, all of the major structural components are permitted to be made of combustible material. The most common combustible building material is wood, thus the term *wood frame*. There may be some fire resistance based on the use of gypsum board or drywall and can be referred to as protected wood frame.

Type V wood frame construction is used in both residential and commercial buildings. The presence of non-load-bearing brick outer walls does not change the classification of the building. A single-family house with nonbearing brick exterior walls is still a wood frame house, not ordinary construction or a brick house or a brick frame house. Any private house, condo, townhouse, and the like would be considered a Type V wood frame structure.

Hierarchy of Structural Elements

Structural elements must follow a hierarchy to avoid load transfer failure and ultimately a building collapse (fig. 2-1). The least dangerous element for major failure is the floor deck material. The next elements are the beams: If a beam fails, then the deck will fail, as well as anything else the beam is holding. Next are the girders: If a girder fails, then any floors or beams the girder is holding will let go. Columns are next on the hierarchy, because when a column goes, all of the elements above the column will fail. This can include several floors of decks, beams, girders, and other columns. The next elements, bearing walls, typically will hold up either two sides or all four sides of a building, and any failure could cause total collapse. Last, and most dangerous, is the foundation. If the foundation fails, the whole building is gone. Foundation failures have caused catastrophic events all over the world.

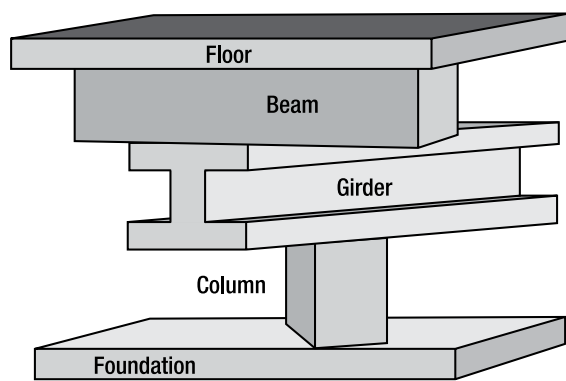


Fig. 2-1. A visual look at the structural hierarchy and the more common types of structural elements encountered during emergency responses. If the bottom fails, all fail. If any of the elements above let go, there will be some type of collapse, which could be big or small.

Loads

One of the keys to proper collapse stabilization of a damaged structure is to support the unstable loads. This can be a complicated and time-consuming operation. A properly trained engineer will be able to calculate the weight of the load the rescue team will have to support. Knowing how the basic types of loads are distributed and how they will affect the remaining

structural elements will give the rescue team an edge in calculating and installing the shoring.

The collapse of the Meidum pyramid in ancient Egypt shows that the problem of loads has plagued us since the beginning of architecture. The distribution of weight, even in apparently simple geometric structures, is a complex and ever-present problem that engineers have to tackle whenever a structure is erected. Again, the purpose of a building's structure is to transfer the loads on a building to the ground.

Given the compressive strength of most structural materials, it is relatively easy to channel loads vertically down to earth. The fundamental structural problem consists mainly of transferring vertical loads horizontally in order to span the distance between vertical supports. The following sections describe some of the loads that must be figured into the construction of that structure.

Concentrated load

A load that is applied unequally over an area is a concentrated load. In certain instances, this can be a dangerous condition that may lead to a structural collapse. In many collapses, a typical stable, evenly distributed load becomes a very dangerous concentrated load that could fail where one or more structural elements have been specifically overloaded. A beam will normally support twice the weight in a distributed load as a concentrated load. This is a very big warning sign for all rescue forces. They must examine the building and determine if any of these overloaded areas exist.

Distributed load

A load that is applied evenly over an area is the safest type of load because it spreads the stresses out equally. Structures are generally designed to have their loads evenly distributed over specific structural elements.

A typical building can handle properly distributed loads. The top panel of figure 2-2 shows the normally distributed load, which are spread out over numerous structural members, thus evenly spreading the weight around. The bottom shows a dangerous concentrated load caused by gravity and partial collapse. The ends of the beams and the floor section are physically overloaded and could fail further if ways are not found

to redirect those overloads (shoring or debris removal) off of the corner.

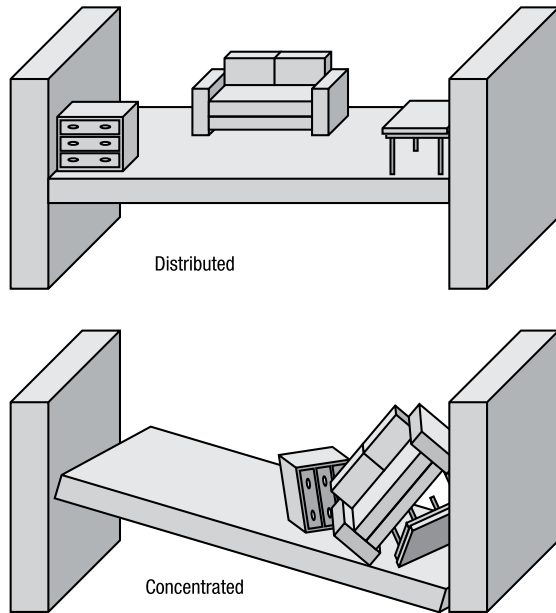


Fig. 2–2. Distributed and concentrated loads

Dead load

A dead load consists of the weight of all the structural components of the building itself. These loads may include but are not limited to all permanent interior and exterior walls, floors, columns, girders, and beams. A dead load also includes any equipment that is permanently attached to it, built in, or considered too heavy to move. The main characteristic of a dead load is its continuous presence; it is a permanent load. In structures built of masonry or concrete, it will be the heaviest load supported by the structure.

Dynamic load

A load that changes value or location rapidly or is suddenly applied is called a dynamic load. A moving elevator or a gust of wind is considered a dynamic load. This is one of the more dangerous types of loads encountered in collapse situations.

Earthquake loads

Earthquake loads are caused by ground tremors stemming from the movement of the earth's surface. Because the dynamic impact forces from tremors are mostly horizontal, they can be resisted by the same kind of bracing used for protection against wind loads.

Impact load

A load that is delivered in a short period of time is an impact load. A structure would normally resist a static load, but if such a load was applied as an impact load, it could cause a collapse. The sudden application of a load provides a unit stress twice as great as that when the load is inactive. When the height of the load increases, the unit stresses increase rapidly. The safety factors built into ordinary structures are rarely large enough to withstand severe impact loads. For example, a hammer that gently touches a nail will make no impact; however, if a hammer is forcibly swung to hit a nail, the impact will drive the nail into the wood. Thus the impact load is equivalent to many times the static weight of the hammer. These loads are very difficult to calculate and are the most dangerous loads in collapse conditions.

Live load

Live loads are all loads other than dead loads. The designed live load of a structure varies with the building's occupancy. These loads can include rain, ice, snow, wind, people, machinery, and any movable nonbearing partitions. The size and weight of live loads are constantly changing.

Static load

A load that will remain constant and is applied slowly is called a static load. A load that can change with time, but whose weight and force are distributed throughout the structure, is also a static load.

Thermal load

Temperature changes can affect the dimensions of structural members and cause expansion and contraction. Loads that experience this kind of change are called thermal loads. All common building materials in use today are affected by this type of load

in some way. Although gravity loads must be fought by increasing the strength and stiffness of a building, the thermal loads must be avoided by making the structure less rigid.

Wind load

The force that is constantly trying to shear a structure from its foundation is a wind load. Wind creates horizontal pressure, which is a serious concern in tall buildings. In this case, a separate structure system different from the system that resists the vertical loads of gravity is required. In very tall buildings, up to 10% of the structural weight goes into wind bracing.

Application of Loads

Axial load

An axial load passes through the center mass of a supporting element. This type of load is straight and evenly applied throughout that element. A structural element will support its greatest load when the load is applied through its axis. The most efficient load direction for a column is axial.

Eccentric load

An eccentric load is perpendicular to the plane of the structural element but does not pass evenly through that element, causing the load to be off-center of that element. This in turn creates an uneven distribution of the load, which then results in the bending of that element, another common cause of collapse. This deflection will cause the column to buckle, which means that the column loading is not properly distributed and the column will fail prematurely.

Torsional load

A torsional load creates a force that is offset from the shear center of the section under consideration and is inclined toward or lies in the plane of that section, resulting in the twisting of that structural element. The worst-case scenario for a column load, torsional loading is eccentric loading on two different planes. A

twisting action will cause a column to fail four times faster than a single eccentric load.

Loads that change from one type to another (e.g., eccentric to torsional) can cause collapse of a structure due to the application of additional stresses. Additional forces applied to structural elements that were not designed to hold those kinds of stresses will cause the elements to fail quickly. There have been numerous catastrophic building failures as a result of this type of loading.

Figure 2–3 illustrates these three types of loads.

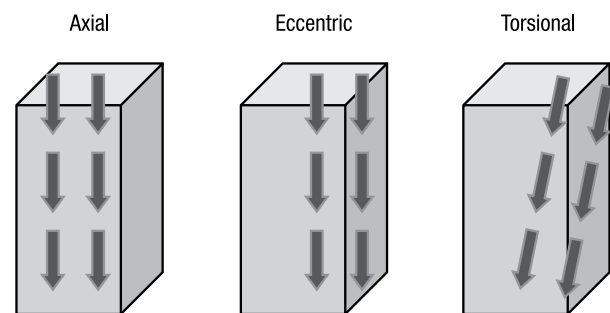


Fig. 2–3. Axial, eccentric, and torsional loads. The load direction indicated by the arrows shows how the load would affect a column or wall.

Basic States of Stress

It is very important to understand the basic states of stress in order to conduct successful rescue shoring operations (fig. 2–4). As a building collapses, it will be subjected to many stresses and strains it was not designed to withstand. All of these actions must be determined and addressed. Knowing the way the structure was stressed will help the rescuers decide where to install shoring.

All structures deform when loads are applied to them. Although these deformations can seldom be seen by the naked eye, the corresponding stresses have measurable values. These stress patterns can be simple, but more often they are quite complex. The most consistent and basic stresses are compression, tension, and shear. All other states of stress are a combination of these three.

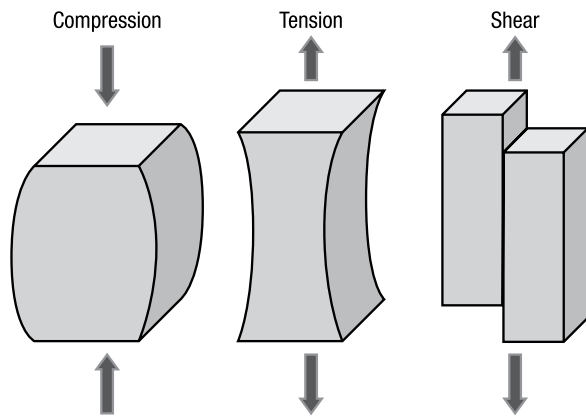


Fig. 2-4. The three basic states of stress and how a structural element would be affected by them.

Compression

Compression is the state of stress in which the particles of a material are pressed together, one against the other. This is the most common state of stress, given that all loads must be channeled to the earth. When an entire element is under compression, the element is being pressurized through its axis from both ends, thus possibly shortening and possibly widening the element under load. Any structural member under compression, whether horizontal, diagonal, or vertical, will act as a column.

Tension

Tension is the state of stress in which the particles of a given material tend to be pulled apart. Tension is normally easy to recognize because it lengthens the material. A load under tension is being pulled through its axis, which may elongate those members as well as make them thinner. Many materials are excellent under tension: Steel, especially wire rope, is an example. Other elements, such as masonry, do not perform well under tension.

Shear

The state of stress in which the particles of the material slide along a plane relative to each other is called shear. One of the main characteristics of shear is that it produces sliding along two separate planes, always at right angles to each other. It occurs when

an element is placed in compression and tension in the same plane. Simply put, shear is a cutting action applied to a specific point or area.

All rescue personnel need to be able to identify the basic loads, know how they are applied, and determine the way structural elements are stressed at incidents. Thorough knowledge of these principles can help to protect victims and rescuers alike in a structural collapse situation.

Torsion

Although consisting of only shear stresses, any element that tends to twist while under stress is considered in torsion. This is a very dangerous situation, because a structural element in torsion is being pulled and pushed in several directions at once.

Bending

The most common combination of stresses is bending. It is the state of stress where compression and tension occur in different fibers of the same structural element.

Columns

Any structural element under compression regardless of its orientation (direction) is technically considered a column. When placed under pressure it will react as such, no matter what direction it is facing. Ideally, all columns will transfer their load along a straight line; this is the most effective method of handling the loads applied to them. Any unbalanced load shifting into a column from any direction may cause the column to fail.

A circular shape is the most efficient for a column. The load will be evenly distributed throughout a circular column. Square or rectangular shapes are used often because their easy fit with other construction building materials, especially in home construction.

Eighteenth-century Swiss mathematician Leonhard Euler realized that the longer a column is, the less it will support. He derived a formula to determine the maximum load a column can bear without buckling. The basic premise is that when weight is applied to a column, deflection in the column will result, deforming

its shape. This will change the center of the column, throwing off the axial load. This deflection will cause the load to be eccentric (off-center), and the column will fail.

Arches

Arches combine the function of beams and columns. An arch is under compression for its entire length. Arches tend to push outward at the base and must therefore be either braced or tied. Some arches are braced by masses of masonry called buttresses, and the removal of any part of an arch can cause the collapse of the entire arch. Almost all arches are masonry.

Although not very common anymore, older structures may have supporting arches located in them (fig. 2-5). Overloaded arches can fail without any warning, an extremely dangerous situation. When even only a third of an arch is overloaded, there is a potential for collapse. A severely unbalanced load or a load outside the center third of an arch may cause the arch to fail.



Fig. 2-5. A large brick arch in front of a school. Although well maintained, this arch is holding up a tremendous amount of weight from the five floors above it. There could be stresses and environmental damage occurring to this arch that are not noticeable, as it was constructed in the 1930s.

Bearing Walls

The structural integrity of bearing walls is essential. If the wall is compromised in any way, shape, or form, serious problems will arise. This presents a major risk for a collapse situation. The worst-case scenario for rescue forces is when the integrity of the foundation is compromised. If there is a foundation problem, we can do nothing about it. The structure must be evacuated and turned over to the building department.

Determine the load capability of the existing wall and check for any damage or visible deformation, which may indicate a support problem. When a bearing wall collapses, it will cause the catastrophic failure of the structure. The bearing walls support all the floors above them, so any failure will cause numerous structural supporting elements to fail.

The prime reason that the bearing wall is there is to support all the floor loads and funnel them directly to the foundation (figs. 2-6 and 2-7). The foundation's only job is to redistribute the building's weight across the earth.

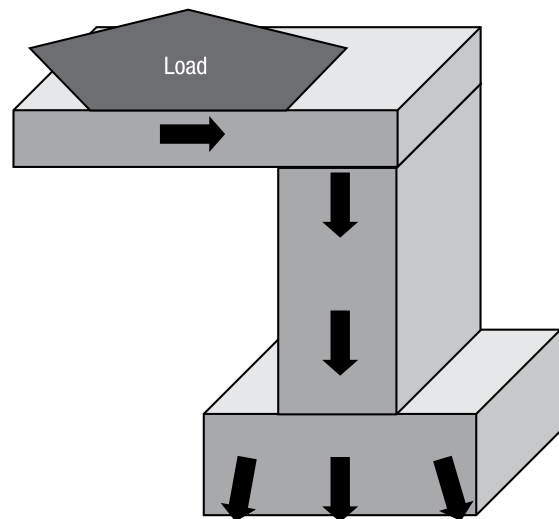


Fig. 2-6. Loads distributed to the ground. The floor loads go to the wall. The wall loads go to the foundation. The foundation takes all the weight from the loads above and spreads it around the ground. This is the basis of all building construction principles.



Fig. 2-7. Roof sections being supported by the roof truss systems. They are several feet on center. The roof trusses in turn are supported as they transverse into the concrete columns. These elements take the roof and beam load directly to the ground through the concrete columns.

Girders

The basic definition of a girder is a beam that supports other beams generally by transferring the load perpendicular to the main load. Most girders transfer the load at right angles to the main load (figs. 2-8 and 2-9).

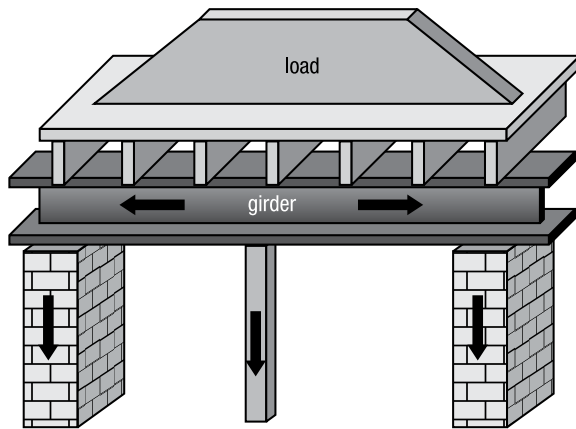


Fig. 2-8. Girder load distribution, depending on the amount of load and the length between the support points, will determine the size and depth of the distributing girder.



Fig. 2-9. The roof and the purlins here are being supported by large steel girders. This is a warehouse with a wide open room to work in. The girders need to be so large because they are spanning a great distance.

The girder load is the main distribution system of the girder. The girder collects specific loads from various points and transfers the loads to specific points. The number of support points the girder has will determine how the load will transfer throughout the structure.

Beams

A beam is a structural element that transfers forces in a direction perpendicular to such forces to a point of support. Since most building loads are vertical and most usable surfaces (floors) are horizontal, structural elements are needed to transfer these vertical loads. The simplest way to do this is to use horizontal beams.

Beam loading

When a beam is loaded, it deflects downward. This deflection will cause the top of the beam to shorten under the weight. This in turn causes the top of the beam to become compressed as the weight is applied to it. As a result of the force on top of the beam, the bottom of the beam will be placed in tension. The greater the compression above, the greater the tension below. Inside the beam, along the length of that beam at some point between the top and the bottom, the force does not change and is known as the neutral axis. This axis is generally in the middle of the beam. This is the most common load situation on all beams when under compression.

Types of beams

The following sections describe common beams in use today (see fig. 2–10).

Simple beam. This is the most common and simplest type of beam in use today. The beam is supported from below and the beam ends are free to rotate.

Continuous beam. A type of simple beam, the continuous beam is not only supported on both ends but also somewhere in the middle in one or more places.

Cantilever beam. This beam is fixed on one end and free to rotate on the other end. The compression and tension planes of this beam are the opposite of the simple beam.

Propped beam. It is fixed on one end and supported on the other end. In the propped beam, the compression and tension planes return to the same as the other beams.

Fixed beam. This beam's ends cannot rotate or deflect; they are locked in position and cannot move. A fixed beam will support twice the load of a simple beam because it transfers the load to the solid material it is imbedded in. It does this by transferring some of the force applied to the beam into its horizontal supports.

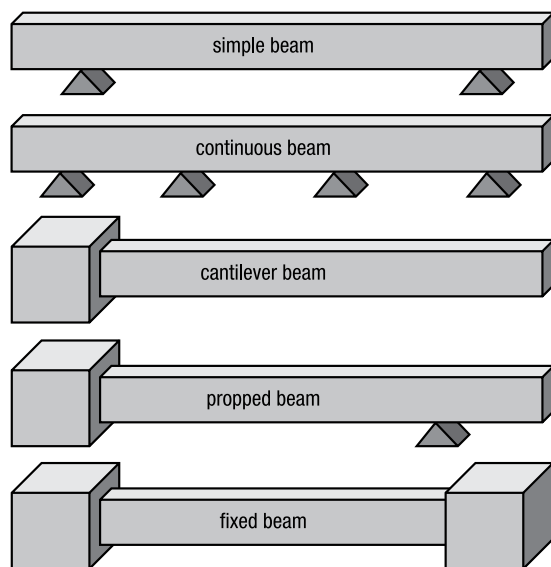


Fig. 2–10. The beams here are typical in many construction techniques throughout the United States. They can be fabricated from wood, steel, concrete, or a combination of any of these.

Beams under stress

When force is applied from above, compression will force a beam down with the weight of whatever it is supporting, and the bottom of the beam will stretch and come under tension (fig. 2–11). The amount of tension the beam is under is proportional to the amount of compression being applied. Every beam has an area within it where both compression and tension will be equal. This is known as the neutral plane, and it is generally in or near the middle of the beam.

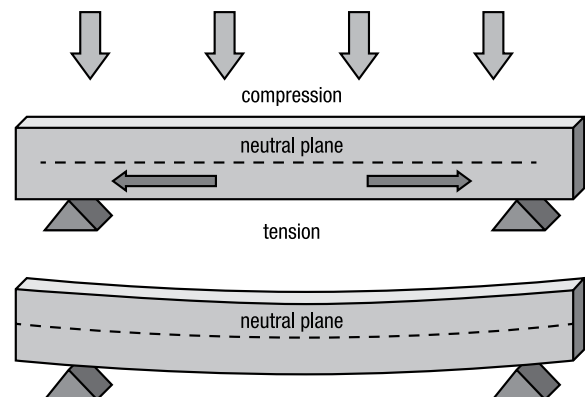


Fig. 2–11. A typical beam is stressed under load. If this situation is encountered in a collapse, it should be reported immediately. Notice that even though the stresses are substantial and the beam is severely deflected, the neutral plane of forces is still in the middle.

Connection Points

In a collapse operation, a building's connection points between its structural supports, floors, and exterior walls are the weakest structural points in the building. These are normally the first places the buildings elements will fail. *Always* check the connection points of any elements when you come upon a section of building that has not collapsed yet. They could be strained or partially failed, just about ready to let go and cause a secondary collapse to occur. Figures 2–12 and 2–13 illustrate two types of connections: pinned and rigid. On the top in figure 2–12 is a typical pinned connection in steel construction. The two beams are attached with a flange that is either riveted or bolted. Either one of these elements can move without affecting the other. On the bottom are two steel elements: one beam anchored rigidly to

one column. This is a very common welded connection point. The weld joins the two elements together to form one. With a solid, movement-free joint, any overload on either element can be transferred to the other member, helping to spread out the overload and keeping the structure from collapsing.

Pinned connection

A pinned connection has a series of simple connectors, such as, but not limited to, nails, bolts, and rivets. These are used to anchor the structural supports together. Rotation of the joint is possible in these connections, and one member does not necessarily bend when the other does. In some situations, this is a good thing, but in others, depending of the stress on the structure, it is a bad thing. For an overloaded condition and possible collapse situation, this would be a bad thing.

These connections do not usually have enough strength to transfer the load to the next supporting member. This will cause a collapse of any portion of the structure that is supported by that member. In collapse situations the pinned connection is the weakest point in the building. This type of connection will be a problem for the rescue team.

Rigid connection

In a rigid frame building, the connections are built into the integrity of the primary structural elements. In a solid joint, members cannot rotate individually when loaded. This causes any load stress to be transferred from member to member. In a possible collapse situation, this is the strongest and most reliable connection. A structure with these types of connections is much safer; the connections can transfer the overloads much more efficiently.

A good example of this type of joint would be a poured concrete monolithic building where the action of the concrete-and-steel reinforcing material can absorb and redistribute the additional weight to adjacent load-bearing members. This will avoid a possible collapse situation from developing.

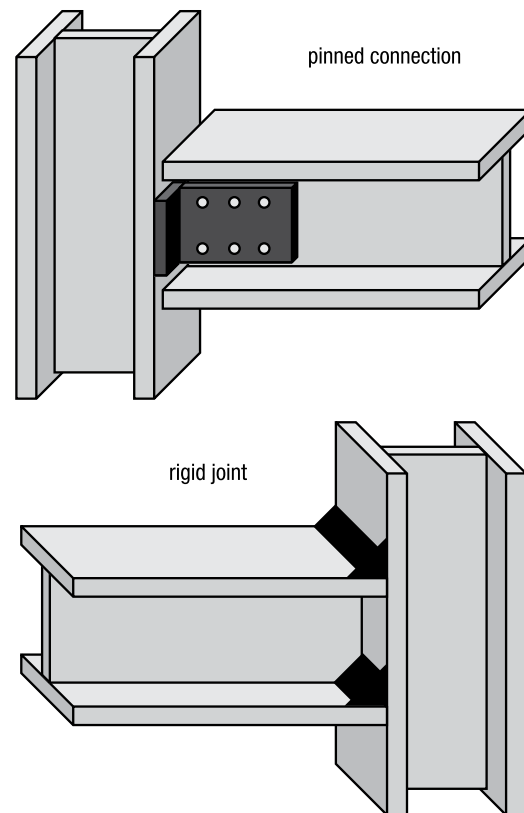


Fig. 2–12. Two types of connections

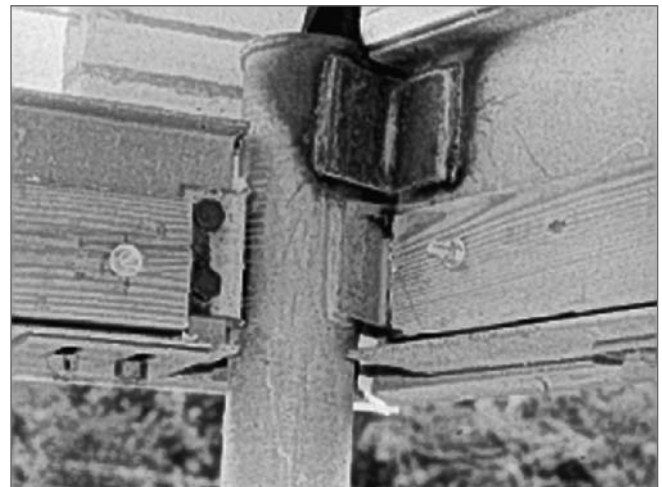


Fig. 2–13. This photo shows both a pinned and rigid connection attached to the same column (not normally done); this could indicate a structural stability problem. On the left is a classic pinned connection, a plate, and several bolts attached to the beam. On the right is a welded connection, which is extremely rigid, also a retrofit, and could be a sign of a serious problem.

Framed Construction

A framed building is one in which walls *do not* support the floors or roof. Instead, these elements are either hung from or rest on a steel and/or concrete skeleton (figs. 2–14 and 2–15). In this type of building, structural collapse can often be localized to the area of the particular element failure. A localized collapse will not transfer through the structure and cause catastrophic collapse.

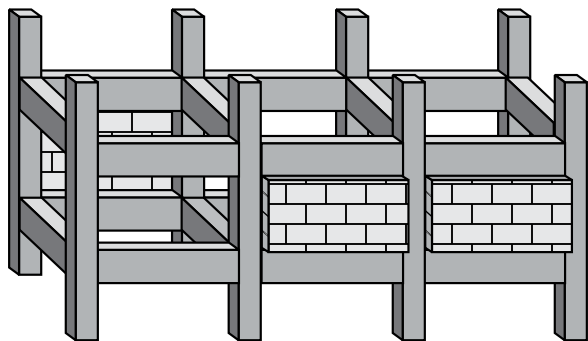


Fig. 2–14. A classic framework for many buildings. The main support of the building is the skeleton of columns and beams. If the infill masonry walls collapsed, that would create a safety hazard; however, the building's structural integrity would be intact.



Fig. 2–15. Typical large commercial construction. All high-rise buildings are framed structures. The exterior skeleton is the framework for the building. The walls are infill and can be almost anything: glass, block, brick, aluminum, steel, or a combination of any of them.

Unframed Construction

In unframed construction, the walls are the main structural elements that support the floor and roof (figs. 2–16 and 2–17). If there is any failure of a bearing wall, column, arch, or girder, extensive collapse of that floor and all the floors above it will occur. For this reason, firefighters must be able to quickly identify whether a structure is framed or unframed.

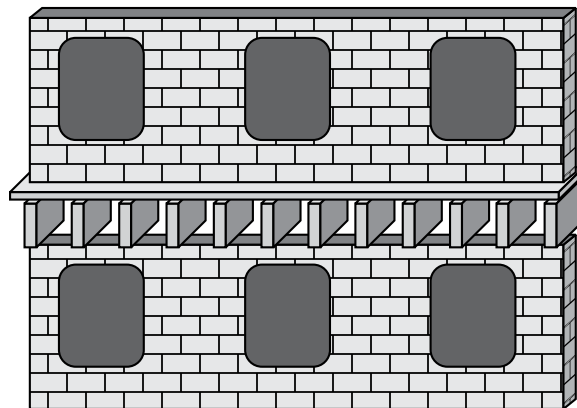


Fig. 2–16. In a typical structure, the exterior walls—whether they are wood framed, masonry, brick, or concrete block—hold up the floors and roof. The exterior walls are erected floor by floor, and then the floor sections are fabricated on top of or hang off of the walls. The sole support for these floors consists of the exterior walls and any combination of interior bearing partitions or columns.



Fig. 2–17. A result of hurricane wind damage. The exterior is masonry, and the interior is wood. The foundation in the rear was partially washed away, and as the exterior masonry walls started to settle, the building's rear masonry wall collapsed. This exposed the wooden interior to hurricane-force winds, causing them to collapse.

Basic Wood Frame Construction

There are three basic types of wood frame construction that firefighters will normally encounter in day-to-day operations: balloon, platform, and braced.

Balloon frame

Balloon framing is common in large private dwellings that are 50 to 100 years old (see figs. 2-18, 2-19, and 2-20). The main characteristic is that only the outside walls of the building have studs running the full length of the building and from foundation to roof. In a fire situation, this causes problems because of rapid fire spread. In a collapse situation, this is a plus because the building will stay together much longer due to the continuous top-to-bottom wall. This type of construction also stands up far better in a natural disaster. Balloon frame buildings hold together quite well in the face of large vibration or wind loads as well.

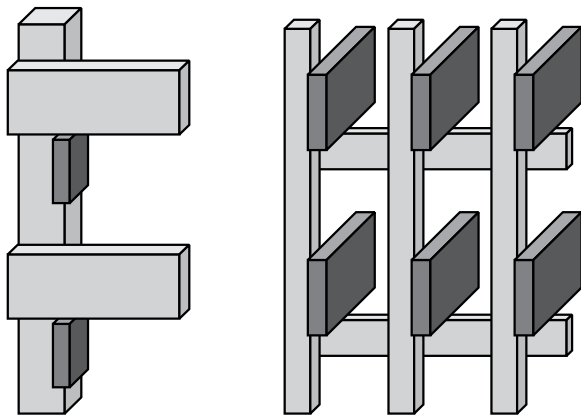


Fig. 2-18. The outside wall construction of a common balloon frame exterior wall. The studs are generally continuous from the foundation to the roof. The floor beams are nailed directly into the studs and placed on top of a 1 × 6 ledger, which is there just to hold the joists in place while being nailed to the studs.



Fig. 2-19. A typical Queen Anne style large private home. This is a classic balloon frame building.



Fig. 2-20. In the attic, the wall studs go straight down to the foundation as one piece. This is a major fire hazard but works well in a collapse situation, keeping the integrity of the outside wall intact.

Platform frame

Platform frame construction has become the norm in the last 50 years. Each floor is erected separately and anchored to the floor, a technique called segmented construction (figs. 2-21 and 2-22). Although better as a fire stop, it performs very poorly in a vibration or collapse situation. The floor sections will easily dislodge from each other and fail.

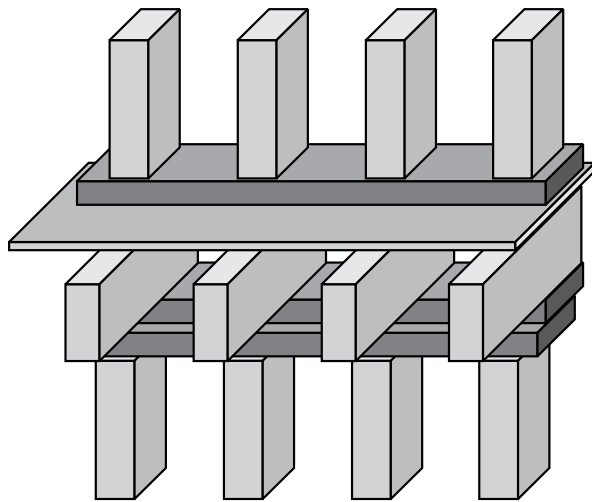


Fig. 2-21. The floor joint area where both walls are connected to the floor beams. This is the most typical construction type in use today, not collapse friendly at all. In any collapse situation, the floor sections will easily separate and fail.



Fig. 2-22. Platform frame construction from directly below the outside wall, looking up a stairwell section between two townhouse sections.

Braced frame

Braced frame is the oldest type of construction and can be traced back more than 100 years. It uses larger lumber than the balloon or platform frame construction, generally 4×4 s for main columns and beams, with full 2×4 infill studs (fig. 2-23). Most exterior walls have a masonry infill for a fire stop. Although strong in its day, they are so old at this point that most connection points are in poor condition and can fail easily. Any buildings still with this construction will most likely be either just plain tired or in some sort of disrepair.

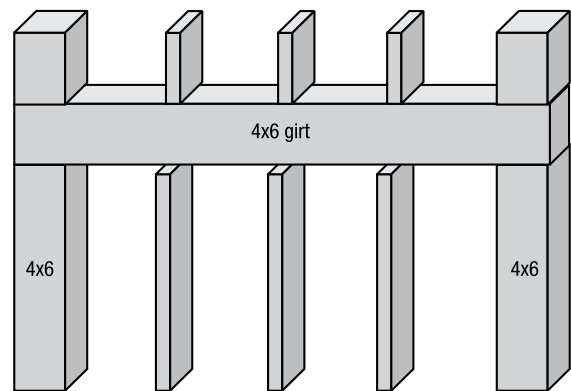


Fig. 2-23. The most common braced frame configuration. Heavier lumber is the norm for this type of building. The outside corners are 4×4 s tied together with a 4×6 girt at floor level. Between these elements are 2×4 s, and all outside walls will have brick noggin infill.

Trusses

Tension and compression are the two basic types of stress that affect structural elements, and materials such as wood and steel can resist them both. Thus it is possible to put together a structure in which every element develops most of the tension or compression and very little bending. This is the principle behind the truss, which has been used for many years (some trusses have been patented since the 1800s). In theory, trusses are created by joining tension struts and compression struts by means of rigid joints. There is a wide variety of such structures; however, they all consist of combination of the same type of rigid element, a triangle. In most trusses today the bending stresses are much smaller than the tensile or compressive stresses they are designed to hold. Building with trusses is very efficient and economical, but for fire and rescue purposes, trusses present several concerns.

Truss hazards

As with any highly engineered lightweight item, trusses are probably one of the most dangerous structural elements firefighters have come across so far. They have been known to fail in 5 minutes in fire situations. Trusses are engineered so tightly that they have little or no redundancy, a major problem in fire and collapse situations. Their high surface-to-mass ratio causes them to burn faster than the average floor or roof beam.

Common metal gusset-type gang nails are used extensively in truss construction (fig. 2-24, fig. 2-25, and fig. 2-26). These plates are sometimes applied with air pad nailers or mallets. They are made of galvanized steel and generally are $\frac{3}{4}$ inch in depth. They are very susceptible to heat and can warp or expand right out of the joint they are nailed into during a fire or high heat condition. Without a doubt, the plates are the weakest link in the truss system.

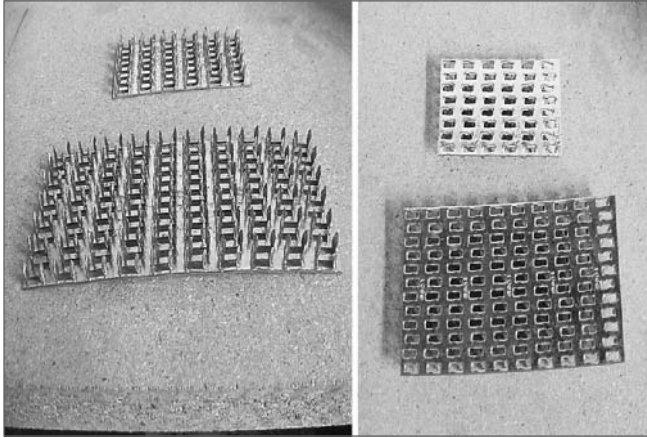


Fig. 2-24. On the left are the “pins.” These are nothing but stamped pads, generally made of galvanized steel. This is the inside of the pad that anchors into the lumber. On the right are what the plates look like from the outside; those holes are the pins or nails punched through.

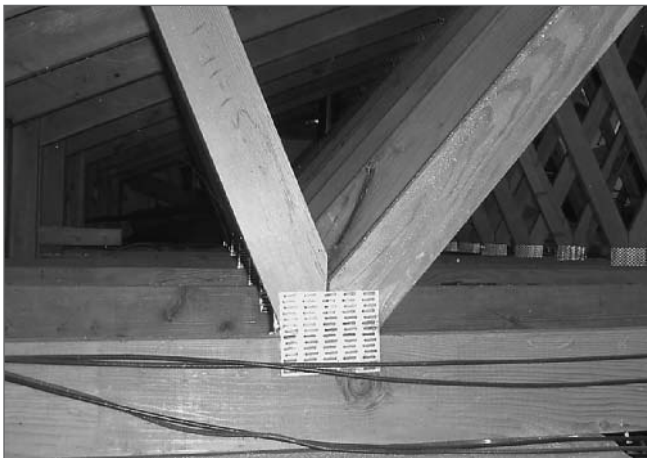


Fig. 2-25. Here is a joint where two web members have been attached to the bottom chord. Notice that the gusset plate only captures about 2 inches of the bottom chord, and the lower right corner of the plate is hitting a knot. The chances of the gusset nails penetrating that knot are slim.

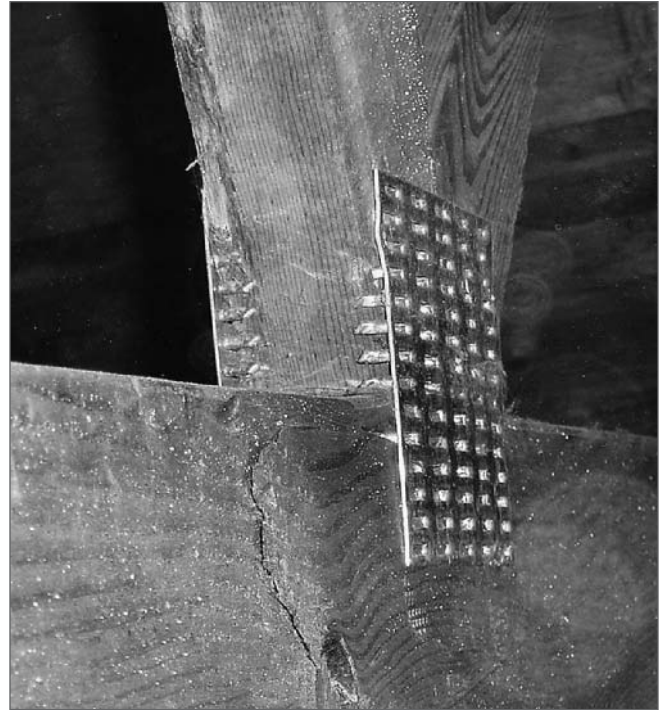


Fig. 2-26. A good side shot of how the gusset plate or gang nails are anchored and how far they penetrate the lumber. In ideal conditions this work fine; however, when an impact load is applied to these trusses, such as occurs in a sudden collapse, they can easily become loose or partially dislodged. This could cause the joint to fail, which in turn could cause the entire truss to fail.

Common truss types

The interior shape of all trusses is a triangle, the strongest shape in geometric design. The floor truss has a top and bottom chord, with interior members under compression as well as tension. The design of the truss makes it extremely efficient, and thus it can be constructed of lightweight material. Although this is great for construction situations, it is very poor in fire and collapse scenarios. If any part of the truss fails, it could cause the collapse of the entire truss. The $\frac{1}{4}$ - to $\frac{3}{4}$ -inch penetration of the gusset plates does not help our cause either, because they fail early in fires.

Parallel chord truss. There are two common types of parallel chord trusses (see figs. 2-27, 2-28, and 2-29). The Pratt truss is a patented parallel chord truss used mainly for floor sections and girders. The patents apply to how the triangular shape is achieved in the web members of the truss.

The Warren truss is a patented parallel chord truss also used mainly for floor sections and girders. The patents apply to how the triangular shape is achieved in the web members of the truss. Both of these trusses are commonly used today.

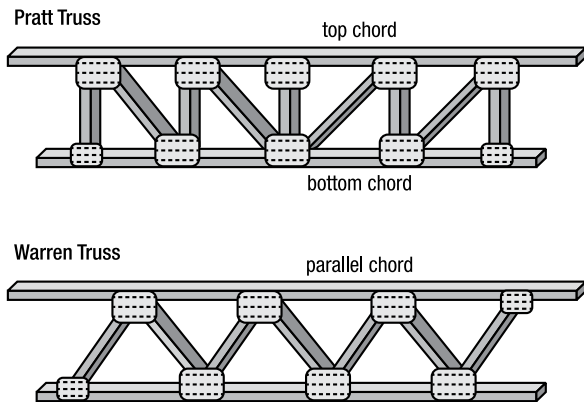


Fig. 2-27. On top is the Pratt truss. Notice the straight leg and the diagonal leg; they can face either direction. There also are several combinations of the diagonals, but generally they all form a right triangle. The Warren truss at the bottom is generally all diagonal members forming equilateral triangles.



Fig. 2-28. A large solid truss supporting other trusses and the outside wall section is used in this heavy timber building. Utilizing an old technique with the large bolts, this truss has been up and working for 75 years. Failure of this truss will bring catastrophic results in a collapse situation.



Fig. 2-29. Here trusses are being used to support a large roof section. The spacing and depth of the trusses are determined by the design of the building, the spans of the openings, and the anticipated roof load. This is the roof support of a very large structure in Salt Lake City, Utah. The roof is actually being supported by trusses running in both directions, north to south and east to west.

Peaked roof truss. Modern buildings with peak roofs may not be of common roof rafter construction but instead built with trusses (figs. 2-30 and 2-31). Many condos, townhouses, and fast-food restaurants have peak roof trusses. All the web members in any of these trusses have a triangular shape. If any part of a truss fails, the whole truss will fail, and with little warning.

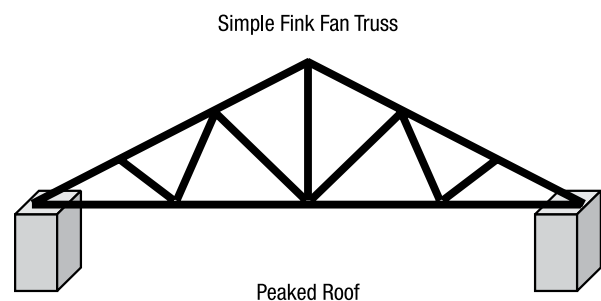


Fig. 2-30. This is a common peak truss design used in condos, townhouses, fast-food restaurants, and now private homes. It is almost impossible to determine from the outside of the building whether it was constructed with trusses.



Fig. 2-31. A metal peak roof truss in use. Behind it is a large section of parallel chord roof trusses. Notice the different triangle configurations. Unfortunately, there are no gusset plates to anchor all the web members to the bottom and top chords. These trusses were made at the site, and all the webs were screwed to the chords with self-tapping metal screws. It is impossible to tell whether there is a truss roof construction from the outside of the structure.

Bowstring truss. Another patented truss type, the bowstring truss is easily identifiable from the exterior of a building (figs. 2-32, 2-33, and 2-34). This is a common older truss used extensively for roofs. Like all trusses, it is very dangerous. This type is generally used in large structures where wide open expanses are needed, including large factories and retail stores. It is named for its bow-type upper section, which transfers the roof loads to the exterior walls. Bowstring trusses can be manufactured of all wood, all steel, or a combination of wood and steel pipes or large bolts. As always, the web members are shaped as a triangle, the strongest shape in geometric design.

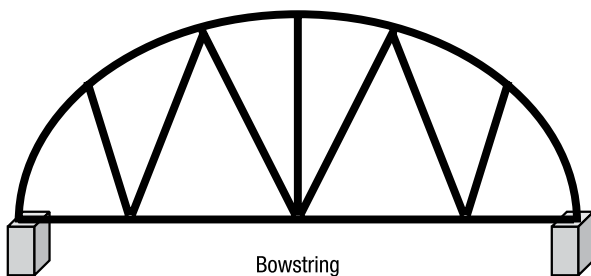


Fig. 2-32. This is the classic Howe bowstring truss, normally easily identified by its telltale hump or arch.



Fig. 2-33. A classic bowstring truss roof and open area factory. The classic bow shape should be a dead giveaway for responders to any incident in this building. If the building is under heavy fire load and it has entered the truss loft, the potential for major collapse is tremendous. Many firefighters have been injured and many have lost their lives fighting fires in these types of buildings. In either a fire or collapse situation, this could be one of the worst situations firefighters will encounter.



Fig. 2-34. The interior makeup of a bowstring truss. Made completely of wood, the interior triangular lattice section gives strength to the top and bottom chords. In this example, the area between the two trusses is built up to make roof drainage easier. This building does not have the typical hump that is a good indicator of bow truss construction. These trusses are designed to hold the load of the roof and not any interior loads. Unfortunately, many manufacturers use the space inside the truss for storage, adding loads to the truss it was not designed for.

Conclusion

All fire personnel need to have a thorough knowledge of building construction in order to make the proper decisions while operating in a structural collapse situation. You will not get any second chances! Without being properly prepared, an incident can turn tragic, and responders can be seriously injured or worse.

Initial Emergency Response

Introduction

A technical rescue operation will run more effectively and safely when a focused Incident Management System (IMS) is used. By employing an IMS to organize all rescue incidents, rescuers will gain the necessary confidence to organize even the most complex technical rescues. Remember that during the initial event the entire IMS model is not needed just yet. As the event develops and expands, so then can your IMS model.

This chapter discusses the ways in which the familiar IMS plans used to organize fire operations can be modified to manage structural collapse rescue incidents. Also described here are collapse-specific operational concepts and guidelines that must be considered while establishing the incident command system.

This chapter has some suggestions on positions and possible responsibilities that can be used in structural collapse operations. These are general operational guidelines that can easily be adapted to any department's needs, personnel requirements, or unique response policies. It is based on several years' worth of collapse experience and initial response. However, it is flexible and is presented here as an informational guide to initial response operations in structural collapse situations.

Primary Concerns for First Responders

Here are seven of the most important concerns for the first responder to consider when arriving at, and initially operating at, a structural collapse rescue incident:

1. Proper size-up and assessment. Size-up will start on the receipt of the alarm and continue until you have left the scene, no matter how long the operation takes to finish. Your assessment of the scene will be based

on both your own visual appraisal and the feedback from your first-arriving units.

2. Utilities shutdown. This must be accomplished immediately, for obvious reasons. If you get reports of a confirmed collapse situation, ask for the utility companies to respond immediately.
3. Fire situation. All fire situations must be addressed immediately. Extinguishment of the fire is the first priority. If people are trapped, then it's a tie. Both need to be accomplished at the same time.
4. Rescue of surface victims. Since we are responding to protect life, all incoming units will have that priority. This needs to be accomplished while size-up and fire suppression are being conducted as well.
5. Initial searches. Upon arrival, immediate surface search and initial void searching need to be conducted. This combination of searches needs to be properly coordinated and organized in order to protect everyone. For example, firefighters cannot be in voids with rescuers working above them because of instability issues.
6. Command post and observation area. Set up the command post as soon as possible, and make sure everyone knows where it is located. A tower ladder in front is recommended in order to have an overhead vantage point, which will give an overall picture of the incident.
7. Proper search procedures. Even though things will be hectic in the beginning, you need to keep track of areas and voids that have been searched. Searching the same voids three times and missing another is counterproductive. Try to set up a procedure as soon as possible, and have teams mark the areas and voids they have looked into.

Protocols

Before an apparatus is placed in service, a protocol for its use must be considered, including the following:

- The type of operations you will respond to and operate at
- The staffing levels you will require
- The qualifications your personnel will need
- Whether you will conduct any inter-agency responses

Operations

The first determinations that must be made are the types of collapse operations you are likely to encounter. Is there a particular type of incident that frequently occurs, or is there a potential for several types of situations? In either case, the team's training and operation specifics should be geared toward specific local needs.

There are several fields of training that must be covered before all your personnel are prepared to respond to this type of incident. Rope rescue, trench rescue, building collapse, confined space, and some hazmat training are just a few of the areas that must be covered. Training in all of these areas should be extensive. The more specialized the training, the better your personnel will be able to function in actual rescue situations.

Staffing

The size of the team and the type of supervision must be predetermined based on the types of problems you will likely encounter. In building collapse situations, one officer supervising no more than five rescuers works well. Most fire departments do not have six-firefighter crews unless they are in a major city. You may have to combine companies to make up specific squads to operate effectively. Also, it is important that the personnel on these teams train together to build confidence in one another's abilities. Responding and operating at major structural collapses without enough personnel can lead to disastrous results. Any secondary collapse or sudden

shifting of debris can cause problems for your rescue personnel if you are understaffed. Sending two three-firefighter engines and one two-firefighter truck is *not* a safe or even remotely feasible response to a structural collapse rescue situation.

Recommended response to specific types of structural collapse situations

The following are guidelines and recommendations for a *minimum* response to each rescue situation. Although these are a few examples, they do not include all the possible examples. For our purposes, assume that you have a major legitimate structural collapse situation. This includes the following conditions: utilities are still functioning; most of the structure is down with unstable remains still up; there is active fire potential; and more than one individual is trapped in the remains of the building. This example is for the initial response, generally 4–6 hours in duration. It does not cover longer term operations where relief will be needed or if a secondary collapse occurs. Also responding must be an incident commander (IC), a safety officer (SO), and a rapid intervention team (RIT).

Private homes less than 2,500 square feet.

Generally, these homes are “stick-built” (all dimensional lumber, 2 × 6s, 2 × 12s, etc.), although in the last few years trusses have been used for floors and roofs. In this situation, as already stated, you would need to respond with a minimum of two dedicated engines and two truck companies (or engine companies if you do not have trucks) dedicated to the search and rescue. If substantial shoring or subsurface rescues needed to be accomplished, you would need the addition of a technical rescue company. Each engine should have a minimum of four firefighters staffing it. Remember, both engines need to take hydrants and be ready to flow water. This eliminates two firefighters from the mix. The two truck companies should also be staffed with a minimum of four firefighters each. Your technical rescue company should consist of at least five firefighters qualified in collapse rescue, with a minimum of 100 hours of collapse training under their belts.

- Firefighters committed to engine company operations: 8
- Firefighters committed to truck work and search and rescue operations: 8
- Firefighters committed to technical rescue: 5

Private homes greater than 2,500 square feet.

These are mostly stick-built, but they also can contain trusses. Depending on which area of the country you are in, they may have a basement as well. Many of these homes have high or vaulted ceilings and balconies, some inside and some outside.

You would need to respond with a minimum of three engines and three truck companies (or engine companies if you do not have trucks) dedicated to the search and rescue. If shoring or subsurface rescues need to be accomplished, you would need the addition of a technical rescue company. Each engine should have minimum of four firefighters staffing it. The two truck companies should also be staffed with a minimum of four firefighters each.

- Firefighters committed to engine company operations: 12
- Firefighters committed to truck work and search and rescue operations: 12
- Firefighters committed to technical rescue: 5

Multistory attached townhouses and condominiums. Most townhouses are either wood or steel stud construction, or a combination of both. Almost all include trusses for floors and roofs—very light-weight construction.

In this situation, you would need to respond with a minimum of three engines and three truck companies dedicated to the search and rescue. If shoring or subsurface rescues need to be accomplished in more than one area, you would need the addition of another technical rescue company. Each engine should have minimum of four firefighters staffing it. Remember, both engines need to take hydrants and be ready to flow water; this eliminates two firefighters from the mix. The two truck companies should also be staffed with a minimum of four firefighters each.

- Firefighters committed to engine company operations: 12
- Firefighters committed to truck work and search and rescue operations: 12
- Firefighters committed to technical rescue: 5

One-story commercial structures. These include a typical mall or a row of stores, or even one large building like some of the larger hardware and lumber chain stores. Older row stores are probably

unreinforced masonry construction, while all the others are most likely masonry block and steel-bar joist roofs.

In this situation, as already stated, you would need to respond with a minimum of two engines and two truck companies (or engine companies if you do not have trucks) dedicated to the search and rescue. If shoring or subsurface rescues need to be accomplished, you would need the addition of a technical rescue company. Each engine should have minimum of four firefighters staffing it. Remember, both engines need to take hydrants and be ready to flow water; this eliminates two firefighters from the mix. The two truck companies should also be staffed with a minimum of four firefighters each.

- Firefighters committed to engine company operations: 12
- Firefighters committed to truck work and search and rescue operations: 12
- Firefighters committed to technical rescue: 5

Multiple-story apartment houses and tenements. These may have localized collapses, or several floors may be collapsed. Many times there will be multiple floors collapsing into the basement. In this case, there is the potential for trapped victims in all the debris, right down to the bottom of the basement. It is not unusual to have very limited access to those areas. If there are multiple victims that are unaccounted for, this will be a long operation. You would need at least three engines and initially four truck companies, with two more on the way for backup and relief, and two technical rescue trained units. In addition, the command staff and RIT would be responding. The engines and truck companies would be involved in both fire protection and search and rescue. If several ambulances are needed, they would have to be called in and are not accounted for in the numbers above.

- Firefighters committed to engine company operations: 12
- Firefighters committed to truck work and search and rescue operations: 16
- Firefighters committed to technical rescue: 10

Multistory commercial structures. The type of construction, which could range from wood and block to steel and glass, will determine the type of equipment

needed. Heavy steel and concrete require specialized tools not normally carried by first-line units. You must call for that equipment as soon as you determine the need for it. That sort of equipment is usually carried by specialized state and federal teams, and it will take some time to mobilize them. In any case, your responding company will be there for several hours on its own. Search as much as possible and identify as many voids and potential victim locations as you can. Try to have a game plan laid out for the removal or stabilization of the main structural elements so you can continue the void search and rescue operations. Due to the weight of the debris and the potential for loads of stock that has to be moved, multiple units will have to be brought in and rotated throughout the operation. In this situation, it is not unreasonable to assume that you might need a dozen units to work the scene and multiple operations sectors set up. For most departments, this would prompt a mutual aid response.

- Firefighters committed to engine company operations: 12
- Firefighters committed to truck work and search and rescue operations: 16
- Firefighters committed to technical rescue: 10

Very large commercial high-rise structures. In this situation you would need to send everybody. Your operation may take several days, and you would need the backup and relief.

Qualifications

It is important to determine the qualification criteria for your rescue personnel. Well-trained and experienced rescuers are a must for successful collapse operations. Experienced responders who are mechanically inclined and have worked in the building trades will be an asset to your collapse rescue company. Also, rescuers should have a minimum of first responder medical training. Remember, certified does not mean qualified! For example, individuals who have no construction background and show up with a certificate stating they took two days of shoring training a year ago, but have not kept up on the skills, will be unable to safely help shore up the building. They just do not have the knowledge, practice, or expertise.

Your team needs to be organized and have standard operating procedures and guidelines for each type of structure in your response area. Your training must be consistent and follow accepted standards in the industry. Make sure you document your training. You need to be training quarterly at a minimum and should be doing two operational readiness exercises a year, if possible. At least one operational readiness exercise (ORE) would be the minimum if your team cannot get together often enough. If you do not train together as a team, you *will not* act like a team when the real thing hits!

Interagency Response

In many areas, large-scale operations involve numerous outside agencies. Frequent interaction should occur with these agencies, and joint training exercises should be conducted. This gives everyone a chance to observe each other's equipment, tactics, and personnel and to iron out the inevitable problems that occur in such operations.

The initial emergency response includes the proper placement of apparatus and crews when units arrive as first-responding emergency service workers. The response protocol indicates the placement of the first- and second-due engines, ladder companies, heavy rescue teams (technical rescue teams), and chief officers. This protocol is meant as a guide for your department and can easily be changed to meet your department's specific needs and or problems.

Overview of Collapse Operations

Five phases of rescue

Immediately following your arrival at a collapse incident, your rescue personnel must function quickly and with precision. Every rescue operation should proceed in stages and according to an organized plan. Although each collapse is different, an organized, systematic approach will ensure a higher degree of efficiency, which will result in saving more lives while minimizing the risk to the responding rescuers.

The location and entrapment of people in collapsed debris presents the rescuer with a host of challenging problems. How well the rescue is conducted and organized will in large part determine the speed with which the victims are removed and the amount of danger the rescuers will face.

Spontaneous rescues. In the first phase, surface victims will be the first encountered. These victims may not be pinned, or they may be lightly trapped. They may be the walking wounded. These rescues will be the first ones made and could be done by passersby, police officers, or first-arriving responders. It is imperative that you document everyone removed from the structure and anyone who has been injured. You need to account for all of the people who either live or work in the structure as soon as possible. Get the victims' names, the location of the building they were in at the time of the event, the location where they were found, and the types of injury. Ask if they know of anyone else in the structure. If they answer yes, try to find out where in the structure the others are located and how many there are. You do not want to spend hours searching for someone already removed from the scene.

Light in-place rescues. In the next phase, the victims are generally near the surface and not pinned or trapped too badly. A quick airbag lift, debris removal, or a lumber cut may be all that is needed. Typically, this will involve getting on top of the debris pile and removing some of it. The pile could be just building furnishings, loose structural elements (beams, columns, partitions, etc.), or construction debris. When you extricate the victims, make sure you use proper patient packaging and removal procedures. In some situations, where secondary collapse is a serious possibility, you need to act quickly. At the very least, victims need to have a cervical collar. Remember, blunt trauma is the major cause of injury in a collapse situation. These rescues are normally accomplished by your first-arriving firefighters. Remember that life is the priority; however, if there is a fire condition, it must be dealt with immediately. If you do not have enough firefighters to make rescues and put out the fire at the same time, you need to attack the fire and stay between the fire and the trapped victims. Once the fire is out, the trapped victims can be rescued in a much safer environment for everyone.

Heavy careful removal. This phase involves victims who are trapped or pinned down by building debris. They are generally under quite a bit of material,

and a lot of digging, debris removal, and crawling through voids will have to be done before the rescue is made. To avoid a crush injury, setting in and shoring, wall breaching, and/or heavy lifting may have to be done. This rescue is most likely going to take some time to accomplish. This phase must be well coordinated and should be carried out by qualified individuals trained in collapse operations and advanced extrication techniques. Normally, rescues in these situations are done by technical rescue units, assisted by search and rescue units.

Body recovery phase. Usually, when you switch to this mode, you would stop the operation and regroup. When the decision is made, you are not in a rescue mode anymore, which can be very hard to do: You are assuming that your firefighters are no longer saving lives. When this is the case, rescue personnel should not take unnecessary risks. The procedure should be methodical, well planned, and completed in a timely fashion but without rushing and endangering personnel. This can be a frustrating time for your teams, because most firefighters do not want to quit before the job is done.

Demolition phase. In this phase, the building or structure is taken down, usually with heavy equipment: cranes, bulldozers, grapplers, front end loaders, and the like. All debris should be spread out in the street on the scene for a final search. After that, it is put in a dump truck or dump body tractor trailer and hauled away.

Five stages of collapse operations

Scene organization and management is difficult to establish at the beginning of any large collapse incident. The IC must try to manage the chaos and at that same time institute an organized command and accountability system. The average collapse situation, if it even can be called that, generally follows the sequence shown in the next sections as a natural progression. Although any one of these stages can be occurring at any time, this is generally how the operations progress in almost all situations. Trying to keep this organized is a very difficult task indeed. Following these guidelines will make organizing the event a lot easier.

Reconnaissance and site survey. The initial survey for the operation will start on receipt of the alarm. All pertinent information needs to be shared

with all incoming units (e.g., building size, occupancy, any hazards, and what caused collapse). During the general survey of the building and the surrounding areas affected by the incident, look for the size and the amount of damage to the structure, how unstable the remains are, potential victims and their locations, any hazards, fire condition or potential for fire, and utility problems (e.g., flooding, live electric lines, and open gas lines). Do a six-sided survey: Check the front, back, both sides, basements or cellars if accessible, and any potential hazards from above. Because collapse debris is extremely unstable, rescuers have to choose their actions carefully. Many of the decisions will be based on where victims are located and how the attempt to rescue one may affect others. It's also important to concentrate efforts where there are known victims and where possible victims are most likely to be found.

Surface victim removal. At the same time as or immediately after the initial survey, efforts should extend to rescuing survivors who can be heard or seen (unless there is a fire condition, then both situations need to be addressed). Even those whose exact location is known but cannot be seen are included here. Although any kind of vibration will endanger the rubble's stability, the benefits of getting on top of the pile to help anyone who is partially buried at the surface outweigh the risks. Experience demonstrates that possibly more than half the victims rescued from a collapse will be at the surface. This stage takes only a few firefighters, so movement of the rubble and debris pile can be kept to a minimum.

Void space exploration and removal of victims. Most collapse configurations leave spaces in which people may be trapped but still have a high chance of survival. These voids are the next priority. Rescuers need to search strong or sheltered parts of a structure, even though no definitive information may be available that any victims may be trapped in such places. This does not mean that every possible hole and corner of a building need to be searched, but that likely areas of shelter should be looked for and fully explored. The primary purpose is to recover living casualties by seeking out places that would have afforded a reasonable chance of survival. The exact places depend on the type of collapse and the extent of the damage and whether a warning of collapse occurred before the incident. The possibility of a warning may have helped some people to exit the building prior to the event, saving their lives. Too much emphasis cannot be given

to the need for searching areas for victims who may still be alive. This is the largest and primary goal of any collapse operation, regardless of what caused the collapse. Areas that need to be searched here would be stronger structural areas of the building, such as stairwells, foundation wall areas, cellars, and under partially collapsed floor sections that have created protected spaces where victims may be spared from crushing debris.

Selected debris removal and shoring operations. To reach the victims who remain after the first three stages (and sometimes to reach those at the surface or in voids), rescuers need to tunnel through the rubble or dig an open trench above the victim. Either procedure might require shoring. Identify these specific locations and then plan out which area will be worked on first. Have your operations chief, rescue officer, and structural advisor work together to determine which debris to remove first. Use heavy equipment if necessary or practical; always search immediately after a section of collapsed building is removed. There may be someone directly under the debris. Stabilize the area if necessary. Many times larger sections of walls or floors need to be cut up to reduce their size to a manageable portion. This is especially true when removing debris by hand or with small machinery. Be very careful how you remove these identified sections, because they may be holding up other items close by. Those items may shift suddenly, causing a secondary collapse or a shift of unstable material.

General debris removal (supervised). After all victims whose locations are known have been removed, the rest of the rubble pile must be removed. At this point, however, the removal is aimed not at reaching a specific point in the pile, but at discovering the locations of any remaining victims. There may be unexpected victims, such as messengers or passersby. The building occupants who are giving information on victims and locations might not be aware of these persons' presence. Heavy equipment such as a crane might be needed, but the work must proceed carefully to prevent further injury to victims. Each load of rubble removed should be checked, as well as the area that has just been exposed.

Incident command overview

A rescue scene can be one of confusion if a command system is not established early in the incident. The command system must be versatile and adaptable to any type or size of emergency or incident. It must be relatively familiar to all personnel to be successfully used throughout the incident and be expandable in a logical manner if changing conditions dictate. The majority of technical rescue operations are most efficiently managed with a pared down version of the full-blown Incident Command System (ICS) model. It is the rare technical rescue incident that requires filling positions such as planning, logistics, finance, the like.

Span of control

The IMS allows for a manageable span of control of people and resources. Utilizing an IMS takes the pressure off of the incident commander (IC). The maximum span of control is seven persons, and the recommended effective span of control of 5:1 allows for the most effective management. The system is set up so that the IC is only communicating to and receiving information from a maximum of five people. Individual managers of personnel and resources within the IMS also work within a manageable span of control.

IMS positions for the typical rescue scenario

The incident commander (IC), also called simply "command," is the individual responsible for the management of all operations at an incident. The IC does not need to be well versed in technical rescue; however, the IC should thoroughly know the IMS. The IC should be stationed at a command post outside the collapse zone. On large, complex, and or protracted incidents, the IC may delegate functional responsibilities by appointing the following officers:

- Operations officer (operations)
- Planning officer (planning)
- Logistics officer (logistics)
- Finance officer (finance)

The IC also communicates directly with the command staff:

- Public information officer (PIO)
- Safety officer (SO)
- Liaison officer (liaison)

The duties of some of these officers and other officers are described in the following sections.

The operations officer is responsible for the direction and coordination of all tactical operations. On modest-sized rescue incidents, operations may fulfill the functions of a technical rescue officer (TRO). At large-scale rescues, operations may designate a TRO. Operations may also interface with the media and other appropriate agencies as necessary in the absence of a PIO and liaison officer.

The safety officer (SO) is responsible for enforcing general safety rules and developing measures for ensuring personnel safety. When personnel is limited, the SO position may be combined with the TRO and/or operations positions. The SO can bypass the chain of command when necessary to stop unsafe acts immediately.

The technical rescue officer (TRO) or rescue team leader is responsible for the rescue operation. This person should be the most experienced rescue technician on the team and assumes the lead role in the design and setup of the necessary rescue systems. When the setup is complete, the TRO will check the entire system. The TRO is the liaison between the rescue site and the command post and designates tactical level positions in the ICS as needed.

Rescue officer

The rescue officer's duties include the following:

Directing and overseeing the actual rescue operation. The rescue officer must be in complete control of all assigned personnel. The officer should be thinking one step ahead of the operations, devising the next mission after the current missions are completed. The troops cannot be standing around waiting for further direction. For efficiency and proper use of personnel, the rescue officer needs to anticipate the next step beforehand. This officer needs to ensure that his or her teams are not being inadvertently interfered with or are conflicting with other operations at the

incident. Two operations next to each other can cause debris shift or building sections to move or slide. This could cause injury to personnel in either or both operations. The rescue officer should interact with operations section chiefs and any other officer in the area to coordinate all their operations. He or she must keep in constant contact with the rescue crew at all times. There are many times in collapse rescues where things can go wrong; sudden evacuation of the area or even the entire site is not uncommon. It is the responsibility of the rescue officer to know exactly where all his or her personnel are at all times; there are no exceptions to this rule.

Establishing rescue sectors. Along with the IC and the operations chief (if there is one), the rescue officer will establish sectors in which to operate. These sectors will be identified on the command chart and plot plan. This enables all personnel to know where rescue operations are going on. If it becomes necessary to augment these operations with personnel or tools and equipment, everyone will know exactly where in the collapse to proceed. Without establishing these zones, confusion can arise about where the specific operations are taking place. The entire collapse zone must be considered and sectors divided up accordingly. All natural barriers in the collapse should be used to facilitate this. For example, in a classic V-shape collapse, there could be three rescue sectors, one sector under each V end and the other on top of the center of the V. Of course, each situation will be different. The general rule is to use the remains of the building to one's advantage, not disadvantage.

Making assessment and size-up. Initially, the scene will be hectic. The rescue officer must immediately determine the potential instability of the remains of the building, the stability of any debris piles, and potential for void spaces where live victims may still be trapped. All of this has to be done simultaneously, but it actually does not take a lot of time to do these preliminary evaluations. As you arrive, start doing your assessment and size-up. As you turn into the block, check to see what type of construction is in the area, the age of the buildings, the general upkeep of the structures, and how extensive the incident is. To do a structural size-up, concentrate on the main building to start with, first examining any standing remains for stability. The main potential for secondary collapse will come from any standing sections of building, whether the building of origin or heavily damaged

adjacent structures. Report your findings to the chief in charge. This evaluation may take just a minute or so. Next, evaluate the main debris pile for stability and void collapse patterns. As you do this, you can get answers to two questions: How unstable is the pile, and which voids will have the most potential for trapped victims? Again, this should take only another minute or so, depending on the size of the incident and your vantage point. The ability to see as much as possible is extremely important. You must be able to take in the whole picture. If you must, change positions—yes, this will take some time. Start preliminary operations on what you have seen so far, then adjust them if you get another perspective of the situation.

Reporting to IC overall assessment and size-up.

Once you have done your size-up and your overall assessment, you must immediately brief the IC. The IC will need this vital feedback and information to establish the incident action plan. Make sure you point out the major hazards and give your opinion on the best places to start searching, such as protected void areas. Point out these hazards visually, and if possible have a solution plan to mitigate the hazards ready for discussion. You may also suggest additional equipment and crew resource needs if necessary to complete the rescue operation, especially if your department responds with minimal personnel.

Establishing rescue staging area(s). There should be a separate staging area for each of your specialized rescue tools. They need to be set up and checked for operational effectiveness. Make sure all the tools work and are organized. When a request comes in for a specific tool, your logistics personnel must know where the tools are and be ready to hand them off without delay. Designate a specific area as close as practical to your operations (outside the collapse zone). Make sure all your rescue personnel are acquainted with the staging area. If you have any standby or relief teams, you may want to stage them there as well. They can help the rescue logistics crew member with the tools and equipment. Check with the IC and operations chief to make sure this is okay first.

Constantly gathering information and providing progress reports. As things progress and missions are accomplished, make sure the operations chief and the IC are kept apprised of all operational status. (In smaller department responses, operations chief and the IC may be one person doing both tasks.) Continuously keep the chain of command above you

apprised of your team's progress. Always keep your eyes open and your brain on high alert. Immediately notify your superiors if there is any change in the structural conditions around you: movement, debris shifting, noises coming from the remains of the building (indicating structural strain or overloading), or other factors that may affect the rescue effort. Remember, just before you finish an assignment, let your superiors know that you are almost done and are looking to be reassigned shortly to a new task.

Establishing a standby or backup plan for rescue operation. Sometimes a good plan gets bogged down. The rescue officer may see a difficulty in accomplishing the mission with the operations procedure that is in place. The officer then must reevaluate that plan and may have to switch strategies. After consulting with your rescue personnel and the chiefs, devise a new plan. This is not uncommon and may have to be done several times throughout collapse rescue operations. *Always* have a backup plan for each operation!

Communicating effectively up and down the chain of command. Communication is always one of the most important aspects of any successful operation, especially a technical rescue one. You must be in constant contact with the operations coordinator above you, any other teams working in your sector, and, of course, the direct personnel working for you. Without constant communication and interaction of all rescue personnel, confusion, duplication of operations, and safety mishaps can occur, greatly delaying the rescue effort.

Making use of operational checklists. It is always a good idea to have written checklists on hand for each type of operation. Keep the checklists in a folder or a bag of some type on the apparatus. Keep it with the officer's riding position; in this way the officer can go over the necessary checklist on the way to the incident. Your "rescue kit" should have a checklist for overall operations, an incident size-up list, a structural assessment checklist, a void search procedures, a safety checklist, and a shoring procedure guide. These are the basic checklists your team will need, but if you have special structures or hazards in your response district, you may need other specialized checklists.

Engine Company Operations

First engine on the scene

The first engine on the scene has the following responsibilities:

Hydrant. The first-arriving engine should immediately connect to a hydrant and stretch a hoseline to the collapsed structure. The potential for fire exists at every collapse, regardless of whether there is any visible smoke or flame showing. At every collapse situation, you must always retain a water supply and be ready to pump water at any time.

Extinguishing any fire. If there is visible fire, it must be extinguished. The top priority at a collapse with fire is to attack the fire without delay. The fire will burn structural elements, causing them to fail, and possibly causing a secondary collapse to occur. If there are victims trapped, the heat and smoke will surely reach them before your rescue team does if the fire is not put out first.

Hoselines. Even if there is no sign of fire, stretch enough line to cover the entire collapse area if at all possible. In the initial stages of collapse, a flash fire or an explosion from leaking gas is a real possibility. This line must be charged as soon as it is in position to protect the rescue personnel who will be operating at the scene.

Protecting members. When members are committed to void search operations, they may not be able to remove themselves from the debris fast enough if a flash fire occurs. They must be covered with a charge line until all possibility of fire has been eliminated.

Apparatus placement. The first-arriving engine should hook up to a hydrant in close proximity to the collapse structure. However, do not block the front of the building. Placing a pumper in front will interfere with operations running smoothly. Always leave enough room for other vehicles and a command post.

Second engine on the scene

The second-arriving engine must also stretch a line. Depending on conditions, there are several options. The second engine crew may want to back up the first

line or stretch to a different area, especially if there are several pockets of fire. Make sure you stretch enough hose to cover the largest area you can. The second engine on the scene has the following responsibilities:

Hydrant. The second engine members should also take their own hydrant and stretch from their own pumper, in case there are problems with the first hydrant or pump equipment. Ideally, this hydrant should be on a separate feeder line (not always possible).

Extinguishing fire. If heavy fire is consuming the structure, the second engine crew may be needed to back up the first engine company. If the fire is threatening another building, they may have to cover that structure. Extensive explosions can cause several buildings to be heavily damaged, and fire can spread rapidly in this situation. Your primary concern is to extinguish the fire to protect any possible victims. Do not abandon your line to rescue someone! Let other firefighters make the rescue. The fire must be put out as fast as possible. Remember, the fire not only spreads upwards and horizontally, but will also drop down into the debris. This will cause major problems with extinguishment, possibly making the whole scene untenable.

Line placement. If the second engine arrives directly after the first engine and no fire is showing, then the crew may divide the structure in half and each will cover one side. Make sure they stretch enough hoseline to cover the building from front to rear.

Protecting personnel. Wherever the second line's crew winds up, their job is to protect the rescue personnel from the dangers of fire or explosion. They should be constantly monitoring the situation, and the line must be staffed at all times.

Apparatus placement. Take a hydrant near the structure but not directly in front of the building. Be sure to not block specialized equipment that may be necessary for the operation or obstruct the view of the command post. Ideally, you can take a hydrant that is fed from a different line from that of the first hydrant. Of course, this not always possible.

Third engine on the scene

The third engine members may have several options when they arrive. They may be used to help augment the stretches of the first- and second-arriving

companies. The responsibilities of third engine on the scene include the following:

Hydrant. Take a hydrant as assigned by the IC. If company arrives before the command post is established, then the third engine crew should go to the rear or the most severe exposure opposite the first- and second-due engines and hook up to a hydrant in that area.

Backup. As assigned by the IC, or if one of the other two units is heavily engaged, back them up. If units are engaged and a severe exposure problem exists, the third engine may have to operate in this exposure.

Rear of structure. If the damage is extensive, then the possibility of sending the third engine to the rear of the structure to cover that area must be explored. If the building is attached to other structures, then the access to the rear may be limited.

Command post. The third engine should generally report to the command post and anticipate backing up one of the other units or covering the rear of the structure with a line. Report in as a group, and scope out a separate hydrant to hook up to.

Ladder Company Operations

First ladder company

Note that in the following discussions, the crew for this ladder company must be made up of at least four people, with six being far more productive. If your department does not respond with at least four firefighters on the apparatus, it will not be able to accomplish these objectives in a responsible time frame.

The first-arriving ladder company will normally be assigned to start an immediate survey of the collapse debris for the possibility of surface or partially buried victims. Obvious surface victims need to be attended to immediately, but do not lose focus! Your crew must do their entire job. At least one or two team members must continue with their assigned missions yet unaccomplished.

The first ladder company has the following responsibilities:

Reconnaissance and size-up. If there is no fire burning and any surface victims have been removed, the first ladder crew may be ordered to start the examination and search of possible voids and crawl spaces that are readily accessible. Even if surface victims are in the process of being removed, this size-up must continue. For the safety of the operating personnel and the continuation of the search and rescue event, this phase must continue until fire department operations have been concluded. Remember, these operations are very fluid, and any new victim discovery or removal or shifting of debris will change the size-up in the area.

Surface victims. Rescuing surface victims is the main priority for your rescue efforts. However, be very careful not to simply enter the collapse to attempt a rescue. The situation must be assessed for the danger of an imminent secondary collapse. Ideally, you can make these rescues and do the assessment at the same time, without too much risk to your personnel. These decisions need to be made rapidly.

Utilities. The officer of this company should have someone immediately determine how to shut down all the utilities and then do so. Often this position is given to the chauffeur. However, this assignment should be determined in your collapse rescue plan, according to your department's response plan and personnel situation.

Void locations identification. After the surface victims have been identified and rescues are in progress, the next step is to start searching for as many survivable voids as possible. Identify and report to the command staff the number and locations of these voids, what type of void it is (pancake, lean-to, etc.), and if the voids can easily be accessed and searched. Work as a team with a minimum of two firefighters. One member can enter the void entrance to assess the situation, while the other should be at the mouth of the void, in full visual and verbal contact with the first firefighter. The second firefighter can then relay to the officer the void assessment.

Hazard identification. While conducting the initial size-up, examine the structure for potential hazards, chemicals, large electrical equipment, open gas appliances or pipe leaks, large pieces of broken glass or sheet metal, and any other items that may be sharp and could severely injure one of the rescuers.

Look for water leaks, hanging wires and cables, unstable voids, and any other potential items that may be detrimental to the health and safety of the rescue personnel. Quickly identify the type of occupancy in order to determine the potential hazards typical of that occupancy.

Apparatus placement. If the first ladder apparatus is a tower ladder or aerial platform, it should be placed in an advantageous position in the front of the collapsed structure. If the first apparatus is not a tower ladder, then the front of the building should be left clear until one arrives or is specially called. The tower ladder will be used for collapse site observation or the placement of a master stream to protect rescuers in case of a fire or explosion occurring.

Second ladder company

The second ladder company has the following responsibilities:

Apparatus placement. If this apparatus is a tower ladder, then it should be placed directly in front of the collapsed structure. The chauffeur and one firefighter should stay with the apparatus. They will operate the bucket and turntable for whatever operations are necessary.

Command post. The second ladder officer will report to the IC for orders and should also check to make sure that all the utilities are shut down. Have one firefighter help a member of the first-due ladder company if necessary.

Utilities. All utilities must be shut down, including water, electric, gas, and any other utility that may cause a problem for the collapse rescue personnel.

Hazard identification. While conducting the initial size-up, examine the structure for potential hazards, chemicals, large electrical equipment, open gas appliances or pipe leaks, large pieces of broken glass or sheet metal, and any other items that may be sharp and could severely injure one of the rescuers. Look for water leaks, hanging wires and cables, unstable voids, and any other potential items that may be detrimental to the health and safety of the rescue personnel. Quickly identify the type of occupancy in order to determine the potential hazards typical of that occupancy. Try to search areas not covered by the first arriving truck company. Continually communi-

cate with the other companies on the scene and relay all pertinent information.

Victims. Surface and partially buried victims should be rescued as soon as possible. When this is accomplished, the search for buried victims should be continued. Try to pinpoint as many victim locations as possible. Work with the other companies on long-term victim removal operations.

Heavy rescue

The responsibilities of the heavy rescue team include the following:

Grid search. In a major structural collapse, a thorough and systematic search must be conducted. The most efficient method of accomplishing this is to separate the collapse remains into workable sections. This is known as the grid search method. When the structure has been divided, then the teams can split up and first search the grids with the most potential for survivable victims. If heavy rescue is not one of the first-responding units, then the initial responding units might have already pinpointed the location of trapped victims. If the victims are extensively buried, then the possibility of void search operations will go into effect. If no victims are visible or have been previously pinpointed, then a methodical and systematic grid search must be initiated. The rescue officer must keep written records of the progress of the search and completion of each grid.

Void search. When the heavy rescue team goes into a void search operation, it must be a precise effort that is properly coordinated with all the team personnel and the IC. The rest of the operational forces must be informed that the void operation is underway and kept apprised of its exact location in the structure. This will ensure that the remaining rescuers will be careful when operating in that area. The officer in charge of the void operation must determine if this will be a long-term operation or a quick and relatively easy extrication. Then the decisions whether to ask for more personnel or equipment will be made accordingly. Possibly some specialized tools and equipment may be needed for an extended rescue removal.

Shoring operations. When shoring operations are indicated, the rescue team must contact the command post if they anticipate that more personnel may be needed. Team positions must be determined, and the

call for a structural specialist should be considered. Getting the lumber and tools required into position in a timely manner takes coordination and numerous personnel. Generally, when shoring operations are indicated, these operations should be completed prior to search operations for safety reasons. All shoring guidelines must be followed to safely stabilize of the structure. Several crews may be necessary to accomplish this task quickly. The use of a shoring crew, cutting team, and lumber procurement team may be indicated in an extensive shoring operation.

Victim removal. The reason the heavy rescue team is responding to an incident is to rescue trapped individuals.

Single victim rescue. When your team is aware that only one victim is to be extricated, all the efforts of the rescue void search team can be put into operation at the one location. In this case, the team can function as an integral unit. Most of the help you need will be for complete debris removal from the building and to procure tools and equipment from the staging area. One officer can be in charge of this operation; directing personnel, requesting assistance, and coordinating and updating the IC will be the officer's primary function.

Multiple victim rescue. When more than one victim is confirmed trapped, the rescue officer must decide if dividing the team may be necessary. This will depend on several factors, including how badly the victims are trapped, how unstable the area is around the victims, and the condition of the victims.

Additional rescue teams. When the operation is extensive or multiple victims are trapped, more trained teams may be required to complete the operation. Keep in mind that when dual operations, shoring and victim removal operations, multivictim operations, or multiple shoring operations are encountered, additional trained rescue personnel will most likely be needed.

Operations of First-Arriving Chief Officers

A small book could be written about the different chief officers' functions in a collapse rescue situation. The following are just a few of the more important

points for the first-arriving chief taking command of the event. Given that each collapse is unique, these are not all the points that may need to be addressed.

The first chief to arrive should make sure, if rescue personnel are already operating, to announce his or her arrival over the radio. Then the chief should proceed to the site of the collapse and take command of the operation. The following actions should be taken:

- Determine from the first units operating what the conditions are, what actions have already taken place, and what they are doing at the present time.
- Size up the collapse area, establish the command post, and make sure that the proper help is on the way.
- Have a staging area set up outside of the collapse area, far enough away not to interfere with the operation. Make sure that the staging area's location is transmitted to all incoming units.
- Request police assistance for crowd and traffic control and to keep roads to the incident free of obstructing vehicles.

Chief officer

The first-arriving chief officer will actually function as the IC as well as the operations chief (OC). There is an extensive amount of information that must be absorbed and analyzed. Then the chief officer must give direct orders based on that assessment in a timely fashion—as in minutes. This can be a daunting task for someone with limited experience.

The first-arriving chief officer has the following responsibilities:

Assuming command. Immediately upon arrival, announce your presence and take control of the site as soon as possible. This is imperative. Without control of the site, chaos and confusion will rule the day. There will be duplication of efforts, confused reports, units reporting the same thing, and convoluted victim and injured civilian reports causing inaccurate counts, just to name a few of the problems. If you must, stop everyone from working except those extinguishing fire or in the process of a rescue. Stop all other operations and have the personnel regroup and all officers report

to the command post. Get your command board going as soon as you can and have all officers report their findings and what operations they have concluded. Try to determine the following from the reports: the worst areas, most unstable areas, fire location if any, potential voids and victim locations, extent of the collapse, any hazmat situations, potential exposure problems. The reports should also give information about whether utilities have been addressed, locations of safe access and egress points, reports from eyewitnesses, and the cause of the collapse. One of the more important things you need to know is the number and location of potential missing victims. Finally, you need to be aware of anything that may be unique to the specific collapse situation. Of course, you need to know all of this immediately. It will take some thought and a few minutes to assimilate this information, organize it, and form a rescue operations strategy. Do this carefully but quickly.

Identification of collapse zones. There are three possible collapse zones: hot, warm, and cool.

Hot zone. The immediate collapsed area, the rescue operations area, and any areas of potential secondary collapse are hot zones. If a wall is still standing but has failure potential, keep the hot zone around the possible fall zone. The hot zone needs to be easily identified and known to all operating personnel. Yellow tape can work well, time and conditions permitting. Unfortunately, this is not always feasible due to many factors.

Warm zone. The command post needs to be in the warm zone, and the staging area should be there as well, if feasible. Your assets should not be too far away from the operation, especially if you need personnel or tools right away.

Cool zone. The place for sightseers, the news media, civilian help, rehab centers, and incoming “experts” whose credentials have not been verified is the cool zone. This zone is well away from danger.

Identification of the staging area. On the way to the scene, start thinking about a location for your staging area. As you arrive, double-check your location and make sure it is accessible from several routes. It is a good idea to keep the command post between the staging area and the collapse operations. That way everyone will have to pass your location before going to work. This will keep some control in the initial stages. If you have enough personnel, assign someone to coordinate the staging area and keep the incoming units

under control while they are waiting to be deployed. Make sure the area is big enough, if possible, to hold all your anticipated assets. Have the area organized for personnel, apparatus, and tools and equipment. Make sure an up-to-date list and accounting of all assets has been established.

Ensuring that utilities are made safe. One of your first actions is to make sure that the utilities are shut off to the affected structures. Assign specific companies to accomplish this and make sure all utility companies are notified to respond immediately. This is one of your top priorities. Rescue personnel should not be operating in a collapse rescue where utilities are live; serious consequences can and will occur.

Using six-sided approach to size-up: top, bottom, all four sides. Always make sure that the entire area as well as the top and bottom of the building are examined in your size-up. Although the bottom may take some time to get into, you do need some assessment of the stability and condition of the structure under the collapse. Check all four sides for stability, access, and exposure issues, if any. Check above for any potential overhead issues if any of the structure is still standing.

Getting input from company officers. As chief, you should always be getting input from all your officers. Try to evaluate all the information given to you. Some may be bad, some good, and some excellent—you need to decide for yourself. But you must listen to all the feedback coming in.

Dividing the structure (operationally) if necessary. It is always a good idea to divide the structure or structures into operation sectors. Chiefs can be assigned to each sector, making the chain of command more distinct and easier to function in. Identify these zones on the command board and the section chiefs in charge of each zone. Have these chiefs identify their areas immediately to any teams operating in their sectors, to avoid any confusion on the part of the rescuers.

Ensuring that IMS is used. Set up your department's IMS policy as soon as you get the scene under control *and* have assigned all necessary units to their objectives. Then organize according to your department's guidelines. Set up your operations, medical, and logistics sections first. This will ensure a smoother transition from first due to a prolonged incident. Your plans and finance sections can be set up when

personnel are available on the scene. Rescue operations are your priority.

Reviewing the five stages of collapse. Immediately upon receipt of the alarm, gather your thoughts about the specific incident and plug in the five stages of collapse rescue. This will help keep the incident progression organized for you. Remember, it is not uncommon to have more than one stage of collapse operating at the same time. You could easily have immediate rescue still going on in one section, while the next area is into the void search stage. Or one area is still in the void search stage, while another is in the selected debris removal stage. Keeping an eye on this will help you determine how to organize and assign your personnel. It could easily be possible that one area of the collapse could be much more difficult to work in than another. You then can concentrate more personnel in specific areas where necessary.

Controlling rescuers. Good luck! This is undoubtedly the chief's toughest job. You will be surprised how many collapse rescue "experts" will show up and tell you how to run the incident the right way. Firefighters, police officers, civilians, and other spontaneous rescuers will be around and operating on their own. With no accountability or direction, they will be a danger to themselves as well as to the firefighters operating on the scene. This situation needs to be addressed immediately. Get all the supervisors of other agencies to the command post. Block off access to the hot zone and secure by police if necessary.

4

Collapse Patterns and Void Search Operations

Introduction

The void search operation is perhaps the most hazardous undertaking in an extremely unstable situation such as a sudden and catastrophic structural collapse. It may very well be one of the most unpredictable and dangerous situations you as a firefighter may ever encounter. This chapter discusses the basic information and organization to safely guide you through this most hazardous of operations.

The five collapse patterns shown in National Fire Protection Association (NFPA) 1670 were obtained from U.S. Department of Civil Defense documents, which were taken from England's *Civil Defense Manual* from World War II. These patterns are based on World War II bomb damage to unreinforced masonry (URM) structures with wood floors and roofs.

There are other, more relevant collapse patterns that can be used to describe the result of extreme forces other than bombs on structures of common, modern construction. Generally, wood and brick-and-joist buildings collapse in five characteristic ways: pancake, supported lean-to, cantilever (also called unsupported lean-to), A-frame, and V-shaped. The collapse type depends on which structural elements fail. Each collapse type creates distinctive voids within the rubble. The five voids are named according to the collapse type. That is, the void created by a supported lean-to is called a supported lean-to void, the void created by an A-frame collapse is an A-frame void, and so on. In addition, individual voids, created when objects in the building break the pattern of the collapse, occur in every collapse situation. It is not uncommon to find more than one type of void in a single collapsed building. In fact, in many collapses this will be the case.

Collapse Void Patterns

Understanding the types of collapse patterns is essential in order to determine, for example, the need for shoring, the types of shoring to be used, possible victim locations, victim access, and the probability of victim survivability. It



is extremely important that your team be capable of quickly identifying these common void types and thus the most probable victim-survivable areas.

Pancake collapse

A pancake collapse pattern is formed when floors let go from bearing walls or there is a sudden impact on the roof or floors (figs. 4-1 and 4-2). In such cases, the floors fail as a unit and stack up on top of each other. Floors can collapse for various reasons, usually a catastrophic event such as an earthquake, major explosion, or severe bearing wall failure. The impact loads from the initial collapse generally will bring down all the floors. Many times the collapse will send all the floors into the basement. Occasionally, the collapse may stop at the first floor because that floor is often imbedded in the foundation slab, giving it more strength. The pancake collapse requires extensive search procedures and prolonged debris removal operations. Victims may be located on several floors and almost anywhere. Very small voids and large amounts of debris can make access to these numerous voids very difficult. These voids are generally made by the building's contents or numerous broken structural members, such as beams, girders, and columns. Natural openings, such as stairwells, are effective points to begin void exploration in pancake collapse operations. These openings, located near hallways where there is usually much less debris, provide a relatively easy and quick access to voids. However, if the stairwell location and extent of the collapse make these entry points inaccessible, you must find an alternative means of void entry. The starting point of second choice is through the flooring between the joists, usually spaced either 16 or 24 inches apart. Work between the joists by cutting through the finished flooring—usually tile in the bathrooms and kitchens and wood in the rest of the building. The flooring is approximately $\frac{1}{2}$ to $\frac{3}{4}$ inch thick, and the subflooring is typically wood that is only $\frac{3}{4}$ inch thick, so cutting between the joists can make accessing these voids quick and relatively easy.

Figure 4-1 illustrates a pancake collapse void. People can be trapped anywhere in the building. Although it may look like no one can possibly live, the truth is quite the opposite. Many people have been pulled out of situations like this, protected by furniture, appliances, and the like. In these situations, victims can be located almost anywhere in the building. The best chance of anyone surviving this collapse is to be

adjacent to a substantial object, which will block the floor above from hitting them.

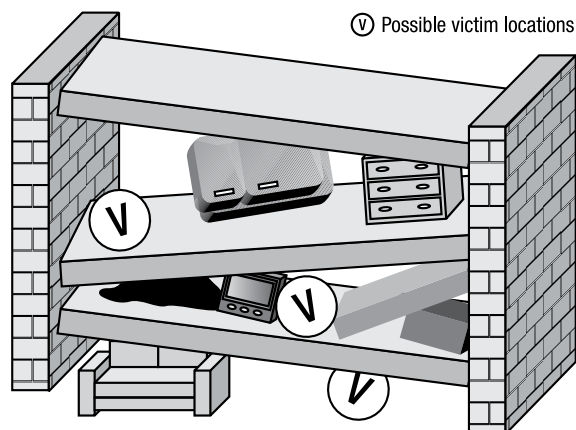


Fig. 4-1. Pancake collapse void

Figure 4-2 shows a complete pancake collapse of a building. After a major earthquake shook the ground, the entire building collapsed onto itself. Hundreds of interior voids were created by many objects in the building. Numerous people were pulled out of this collapse over a period of several days. Remember, even in the most devastating collapses, survival is a real possibility.



Fig. 4-2. A complete pancake collapse of a building

Debris on the floors dictates where and how many individual voids may be located. Strength and size of the material on the floors (e.g., furniture, machinery, and appliances) will dictate how many voids will be present. The best way to access these floor voids is through natural openings: roof hatches or openings, stairs, elevator shafts, and breaches through floors or walls. Try to find hallways, because there is generally less debris in them.

Supported lean-to collapse

Failure of one bearing wall is usually the main cause of a supported lean-to collapse pattern (figs. 4-3 and 4-4). Floor beams can also pull away from their supports on one side of the structure. The other side of the floor stays anchored to or propped up against the opposite wall. The possible causes for this are foundation failure, rotten beams, vibrations, fatigue bearing wall failure, and overloading. Whatever the cause, in a supported lean-to collapse, the floor fails at one end and stays anchored at the opposite end. The floor falls until it rests on top of machinery, furniture, debris, or the next floor. People are usually found on top of the floor near the bottom, by the wall where debris has slid. The best chance of anyone surviving is being located along the wall area that has stayed intact. It may be easy to access voids under the collapsed floor. Often no shoring is necessary for a search. If the entire floor section stays intact, which it does quite often, that may be enough to protect the rescuers from falling debris. Be careful moving debris; once we move or shift without shoring, we could create unstable conditions.

Figure 4-3 illustrates a supported lean-to collapse. The wall on one side gives way, and the floor drops down until it is either supported by the next floor or substantial objects on the floor below. Victims have been located at the edge of the building in the main debris pile on the sloping floor section. The best chance of anyone surviving is to be alongside the wall area that is still intact.

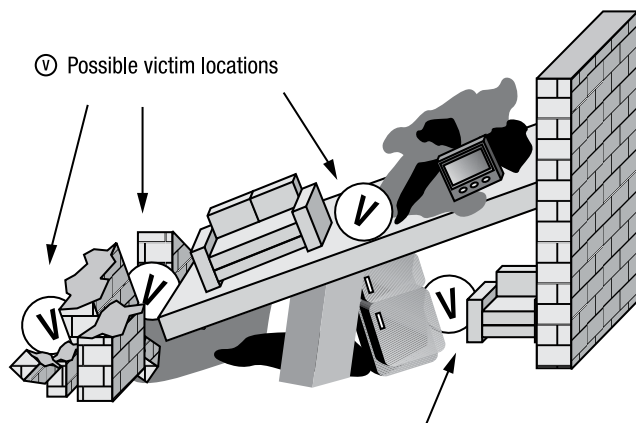


Fig. 4-3. Supported lean-to collapse

Figure 4-4 shows a collapse at a brick apartment house in downtown Manhattan that was converted into a store. The occupants removed a section of the

interior bearing wall, causing the interior of the structure to collapse. Numerous voids were created on the sides of the building on several floors. Firefighters were able to search these voids with some degree of difficulty. However, it was done in a timely fashion, and no victims were found on the upper floors. The best chance of surviving this is to have been near the outside left wall. Anyone on the floor above would be traumatically injured and would not have a good chance of coming out of this without severe injuries.



Fig. 4-4. Supported lean-to collapse in a brick apartment house

Cantilever collapse (unsupported lean-to)

A cantilever or unsupported lean-to collapse pattern occurs when one bearing wall totally fails, causing the floor beams to pull away from their supports on one side of the structure (figs. 4-5 and 4-6). The other side of the building stays intact, and that section of the floor stays anchored. Thus the entire floor is suspended, at least temporarily. These failed ends hang precariously and can let go at any moment. The cantilever is without a doubt the most unstable and dangerous type of collapse. It is nearly impossible to predict how the floor will react under additional stress or movement. The floor end has no

solid support and could be just hanging on electric cable or pipes. The slightest additional impact could cause secondary collapses.

As figure 4-5 illustrates, in a cantilever collapse, the floor, or floors, still stay anchored to the wall opposite the one that failed. (It is not uncommon to have more than one floor hung up like this.) In this very unstable situation, the sections may let go at any time and will fall directly on top of the main debris pile, which is where most victims will be trapped. The victim location is the same as in the supported lean-to collapse pattern. People in the main debris pile will not have a good chance, but inside the structure they stand a far better chance of surviving.

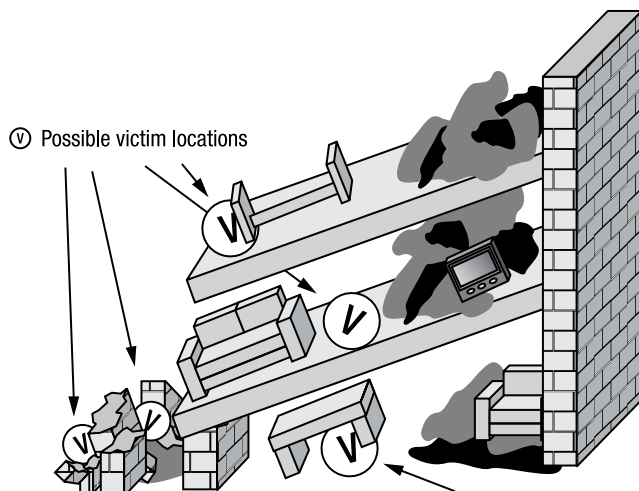


Fig. 4-5. Cantilever collapse

Figure 4-6 shows a five-story URM apartment house that was converted into a commercial establishment. During renovations, a section of exterior bearing wall was removed from the center of the structure. As the building collapsed, it formed a cantilever section in the rear of the building. Three trapped people were rescued, and one victim perished.



Fig. 4-6. Cantilever collapse at a converted apartment building

A-frame collapse

An A-frame collapse pattern is the opposite of a V-shaped collapse. The flooring separates from the exterior bearing walls, but is still supported by interior bearing or nonbearing walls. This type of collapse can be caused by earthquakes, foundation failures, flooding, or the excavation of an adjoining area. The forces applied to the structure are enough to cause it to partially fail, but not enough to cause a total collapse. For example, if the exterior walls bulged out and the roof came down, it would still hinge and be supported by various interior bearing elements. The roof or floor areas can let go from the walls, causing the outside ends to slide down to the next floor or land on top of items strong enough to support those floor ends. The highest probability of survival is for victims found near existing, still intact partitions in the center of the collapse area (fig. 4-7). On the floor just above, which has collapsed, a victim could be pinned near exterior walls and have a much lower chance of survival.

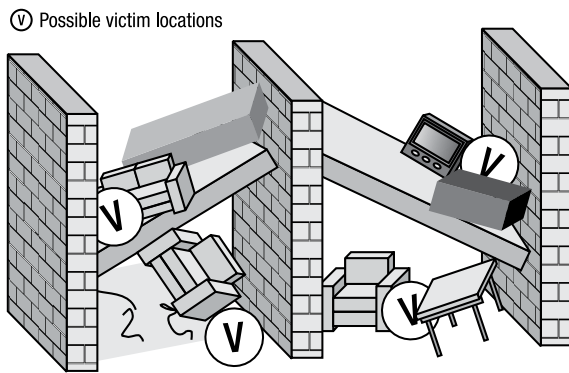


Fig. 4-7. A-frame collapse

V-shaped collapse

A V-shaped collapse pattern is the opposite of an A-frame collapse. The bearing partition wall lets go, and the floor either breaks or separates from its connection points in the center and hinges down. The crude shape of a V is then created (fig. 4-8). This type of collapse may be catastrophic or localized, depending on how much force the structure was subjected to. The exterior walls stay intact, and the interior bearing or nonbearing partitions give way. This can be caused by floor overloads or defective interior structural elements, such as columns. Depending on the type of building and its structural design, such as a large framed building, a V-shaped collapse can be relatively localized. Voids are created on both sides of the load failure. Occupants on the floor below, located only a few feet from these areas, usually have a high survival rate. The sheltering effect of the collapsed floor prevents debris from landing on them. Victims who were on top of the collapsed floor are usually at the bottom or near the center of the V, trapped in the rubble in various places. Because of the large amount of debris concentrated in one area, the survival rate for these victims is not high. As long as both exterior walls are intact, the void created after the collapse may be relatively stable.

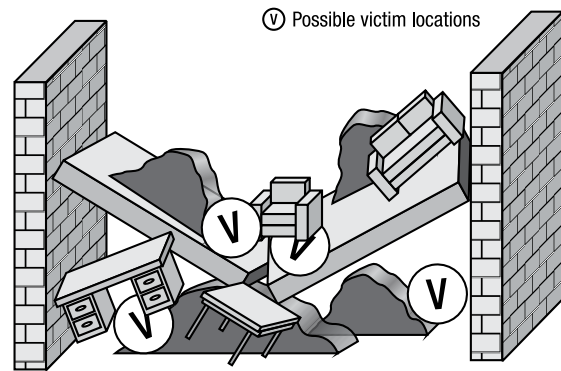


Fig. 4-8. V-shaped collapse

Individual voids

Individual voids exist in almost every collapse situation. They are created by the presence of large objects that support the collapsed flooring in several or many different areas. In commercial occupancies, items such as machinery, large office equipment, and furniture contribute to the formation of these voids. In residential structures, the voids may be created by furniture and large appliances.

Floors in structures of lighter weight, such as single-family dwellings and attached wood frame houses, weigh approximately 10–20 pounds per square foot. Common appliances and furniture break the fall of this kind of floor, so several voids can exist throughout the collapsed area. In heavier masonry buildings, floors weigh approximately 120–150 pounds per square foot, so voids are limited due to the large amount of crushing debris caused by the extra weight. In any event, searching individual voids is a key undertaking in almost all collapse search and rescue operations.

Earthquake-caused collapse patterns

The unique motions caused by earthquakes can cause severe forces and overloads to all types of structures. In most earthquakes, the forces applied to the structure are proportional to the weight of that structure. In recent times, engineers have been able to make most buildings “earthquake resistant.” This is done by increasing a structure’s ductility and redundancy, enabling the structure to withstand some of the violent forces applied to it from earthquakes. These

destructive forces will affect the lateral resistance of a building, typically the building's X bracing, moment frame sections, and shear walls. If any of these items are overloaded, the structure could collapse. As these items fail, the effects of gravity take over, and the building will fall to the ground. Examples of some of the more common earthquake-caused collapse patterns follow.

Offset collapse. This pattern occurs because of the unique nature of light frame construction (figs. 4-9 and 4-10). The lateral-load-resisting walls for these structures can be characterized as skeleton-and-membrane type of construction. The membrane (typically the outside sheathing) acts as lateral resistance, while the skeleton (the building's framework and supporting walls) supports the vertical loads. When an earthquake motion causes the sheathing to fail, generally in the first story, the upper stories will start to lean over or rack.

The vertical load capacity of the studs and post is normally still intact. This will cause the structure to progressively tilt and lean over until it has offset about as much as the height of the first story or stories where the lateral membrane has failed.

In figure 4-9, notice that the upper story still stayed intact as the skeleton frame held together. This collapse has happened with soft first stories under occupancies. Typically, with residential parking located on the ground floor with open areas and little lateral support, this is the result. The lower floor structural supports not laterally braced very well will let go. This causes the more intact upper floors to fall and settle down on the fallen supports yet still stay relatively together as a unit.

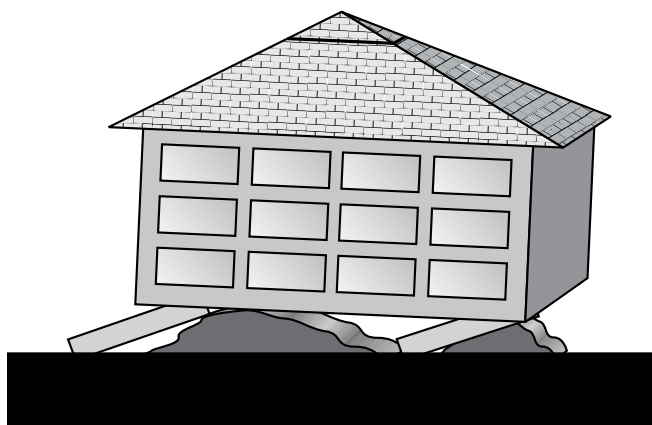


Fig. 4-9. Offset collapse

Figure 4-10 shows a two-story private home where the first-story exterior wall collapsed. This caused the upper story to slide and lean over the edge of the damaged wall, causing the corner of the building to collapse. These firefighters are stabilizing the base of the upper-story framing in order to keep the floor from collapsing further. This is done to enable them to search the lower floor area.



Fig. 4-10. Offset collapse at a two-story private home

Wall fall collapse. In a heavy wall or URM building, wall fall collapse will develop when an earthquake motion causes high shear and lateral forces to be forced into the heavy walls (fig. 4-11). This in turn causes the connections between the walls and the floors or roof to be overloaded and fail. The walls can then fall outward, leaving the floors or roof partially unsupported. The pattern can be slightly different in other types of construction.

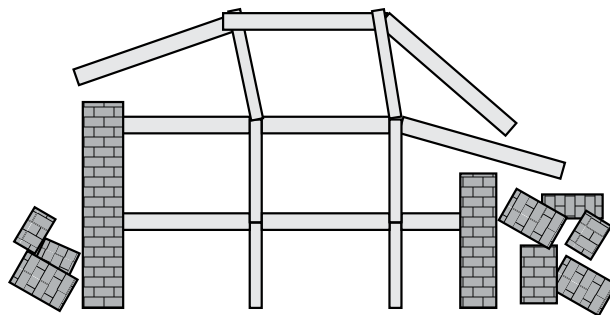


Fig. 4-11. Although sections of the exterior wall have collapsed, the large interior structural supports still keep most of the building standing. Victim potential here would be on the top floor or the two outside sections that the walls have fallen into.

Upper-story walls and parapets will generally fail first. This happens because the walls are normally weak laterally, and the motion of the earthquake causes the forces applied to the structure to be at their highest at the top of the wall. Then the motion forces will decrease depending on the height involved. The collapse fall zone for this type of building is generally less than the height of the building because the masonry joints cannot withstand much lateral pressure. The walls will lean slightly and then collapse into sections or piles of rubble. Many URM structures have interior occupancies with numerous interior bearing and nonbearing partitions. They are normally lightweight and do not collapse as easily as exterior masonry walls. If the entire exterior URM walls fail, then it is likely that the whole structure will come down.

Wall fall tilt-up construction. This situation is different from the wall fall collapse just described. Reinforced concrete walls, sometimes cast on-site and sometimes precast, generally 6–8 inches thick, will almost always fall as a unit (fig. 4–12). In this case, the collapse zone will be at least the height of the wall. This type of construction is normally used for warehouse occupancy with long roof spans and few interior partitions. The roof above will also come down. The roof can lean or possibly totally collapse onto the ground or land on whatever objects are being stored in the warehouse itself.

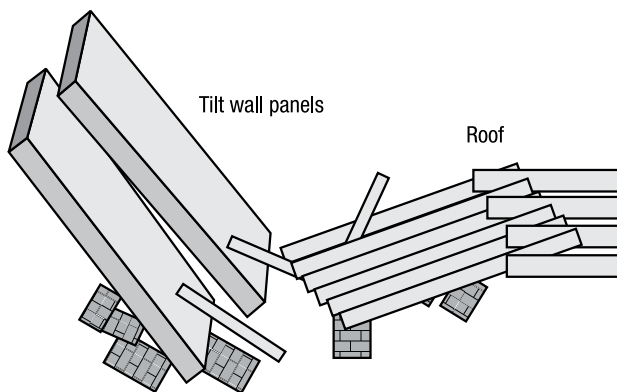


Fig. 4–12. When these precast wall sections let go, they tend to stay together or separate at their joints. They can fall completely or hang up on whatever items may be outside. The roof, from the edge to the nearest interior support, if any, will also come down. Victims will most likely be under the fallen roof sections.

Overtake collapse. This pattern will develop when the earthquake motion causes high tension and or compression forces in the exterior columns of taller, thinner building that do not have adequate ductility in their original designs (figs. 4–13 and 4–14). In a building with heavy floors, the columns will generally fail in tension at a splice connection, which will cause the floors they are holding up to collapse. In a heavy steel building, the columns normally fail in the compression mode by buckling, causing the same result.

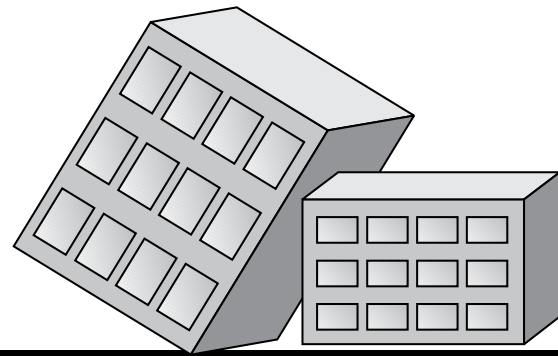


Fig. 4–13. What may happen in an overturn collapse, especially when adjoining structures are involved. People could be trapped in both structures.



Fig. 4–14. A condo structure whose foundation failed in the rear, causing the whole building to tilt back and lean precariously.

Soft first-story collapse. This pattern will develop in a building that has occupancy in the first floor and that does not permit many shear resisting walls to be present (figs. 4-15 and 4-16). This could be a garage or store, for example. The upper stories, generally offices or apartments, will have shear walls. This presents a unique situation. The earthquake motion becomes concentrated in the soft first-floor walls, the minimal amount of shear resistance is overcome, and the story collapses. In many situations, especially in lighter construction such as smaller residences, the upper floors stay relatively intact. People occupying the building can be trapped in debris under the collapsed floor or injured in the upper stories from materials falling on them. Victims under the collapse structure on the first floor are in the most danger. The upper floors would cause more traumatic injuries than anywhere else.

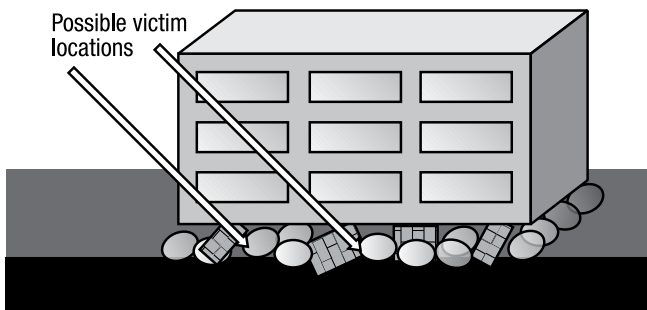


Fig. 4-15. The initial search should be the remains still standing. Check for injured or incapacitated people. The most thorough, lengthy, and dangerous search will be in the collapsed first floor. Here is where most of the trapped and severely injured victims will be located.



Fig. 4-16. Rooms on the upper floors and the lower floor of this motel had wide open areas and minimal shear walls to counteract the motion applied to the building.

Random fall collapse. This pattern will develop when the earthquake motion causes overloads in the connections between the precast elements. These connection points are the weakest part of the entire structure. When the connections fail, the affected parts fall and a progressive collapse can be triggered that may involve some of and possibly most of the structure. This type of collapse most often occurs in economically engineered precast structures, such as parking garages (fig. 4-17).

Once this collapse starts, it is hard to predict how many parts will be involved, but gravity will bring them directly to the ground below, causing a potentially dangerous and very unstable situation. Victims can be located throughout the entire section that has collapsed.

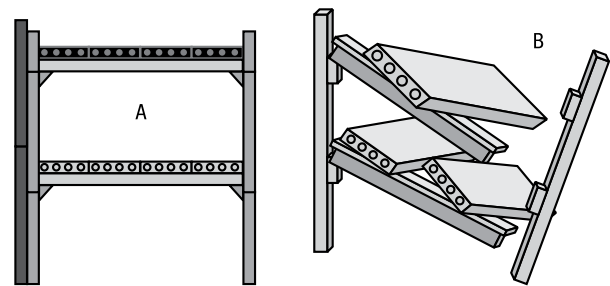


Fig. 4-17. A typical parking garage type structure, basically an erector set of precast concrete sections.

Wind-driven collapse patterns

Depending on its speed, wind can cause many detrimental effects to structures. Light projecting parts can be lifted away and deposited at great distances. Severe tornado winds can shred and rear apart light structures. A common collapse pattern for partially remaining structures is when the roof is literally lifted right off the building, many times in one piece.

Structure building types damaged by wind. Several types of structures are more susceptible to the effects of winds than others. For the most part, larger and more heavily built structures generally stand up better (schools, hospitals, etc.). However, wood frame buildings do not fare well (except balloon frame, which hold up substantially better). Most wood frame buildings are easily penetrated, and their roofs come off easily. Mobile homes are the worst for any natural

disaster, especially wind. They can easily be torn to pieces. Preengineered and hanger-type structures are easily damaged. Their light exteriors may be stripped off, thus exposing the interior to uplift force and rapid collapse. Any building with high walls and long roof spans can also succumb to the effects of strong winds.

Roof lift-off collapse pattern. In buildings constructed as light frame and heavy wall construction, this pattern will develop when the roof is lifted off, either due to aerodynamic lift or the wind penetrating the structure (figs. 4-18, 4-19, and 4-20). Once the lateral transfer bracing provided by the roof to the walls has been removed, the walls are very vulnerable to failure. They have been known to fall outward as well as inward. The wall failure may be limited somewhat at corners or if there are other elements that can provide lateral support, such as encased columns or interior walls anchored to the outside wall. Generally, the wind forces are generated on the exterior of the building based on the height, the ground surface roughness, and the velocity of the wind. The weight of the structure may have little effect on stopping the wind except to resist uplift forces. Unless the building is penetrated, windows taken out, or walls pushed in, the forces of the wind will be all exterior. Objects that have essentially become airborne missiles can affect the structure, depending on their size and velocity and where they penetrate the structure. The wind pressure will act inward on the windward side, and outward on the other sides of the building and the roof. There will be special concentrations of outward force occurring at the corners and the roof edges, especially where there are overhangs.

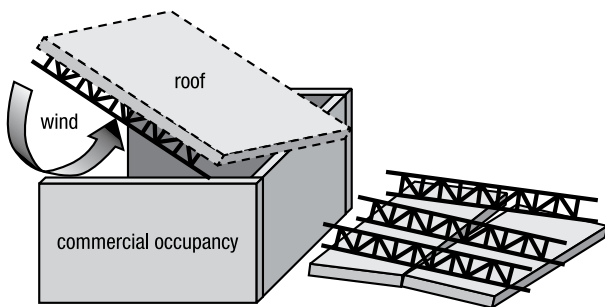


Fig. 4-18. The wind from a tornado or hurricane can come in and take the whole roof off of a structure.



Fig. 4-19. The front of an auto supply store after a hurricane came through, wiping out the glass front doors and display windows. When enough wind got under the roof, it was separated from the building.



Fig. 4-20. Here is the result of the wind force. The entire roof came off and landed in the backyard of the building. Can you guess which direction the wind was blowing?

Explosive blast collapse patterns

Explosive blasts can produce extremely high, but generally short duration, pressures on surfaces and structures in all directions from the point of ignition. Lightweight and lightly built structures will be completely blown away, in no particular pattern. The effects of an explosive blast are very different from that of an earthquake or other natural disaster. In the case of blast, the pressure is exerted equally in all directions from the origin; the force is most intense at the point of ignition and moves in a spherical way. It gradually loses force the farther it travels. The exterior explosion causes shock waves to overpressurize the entire struc-

ture, including the interior as well as the shock wave finds its way in through numerous openings. Secondary effects can include airborne missiles and very short duration ground shaking (tremors). The most common collapse pattern is lift and drop.

Lift-and-drop collapse pattern. This pattern develops when a blast originates within or immediately adjacent to a structure (figs. 4-21 and 4-22). The pressure wave radiates out in all directions, but the most detrimental effect is to cause upward pressures on concrete slabs that have been designed for only gravity forces. If the reinforcing steel has only been provided to resist the downward force of gravity, the concrete will have only its weight to resist the upward blast pressure. Given that concrete is weak in tension, the slabs are lifted, destabilizing adjacent columns, and a significant part of the structure will fall to the ground (or basement) below. Part of the damaged slabs may end up precariously hanging from the remaining structure. Lightweight and ordinary framed buildings are normally leveled. Heavier steel and concrete column buildings may survive, but the floors and walls will be heavily damaged.

As illustrated in figure 4-21, in a lift-and-drop collapse, the explosion lifts up the floor sections while simultaneously applying drastic lateral forces against the interior columns and exterior walls. The connection points from the floors to the columns fail. When the force of the explosion subsides, gravity will take over. The now unconnected floors drop down, crashing on top of each other and into the now weakened structural supporting elements. A lift-and-drop collapse can create pancake, supported lean-to, and cantilevered floor collapse patterns all in the same localized area.

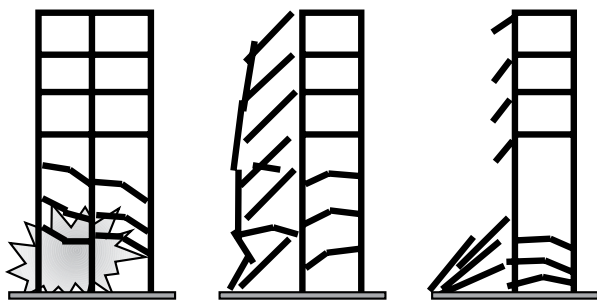


Fig. 4-21. Lift and drop collapse



Fig. 4-22. The back of the Murrah Federal Building at Oklahoma City early the next morning after the bombing of April 19, 1995. The explosion caused a lift-and-drop pattern, with nine floors collapsing to rubble almost two stories high with almost no voids. There were some supported and cantilever floor collapse patterns inside the building.

Multiple collapse types

It is not unusual to have more than one collapse type at a given incident. In fact, it is generally more common in URM and wood frame buildings to have more than one type of collapse pattern.

Figure 4-23 shows a major collapse in New York City on October 24, 1988. Workers were removing a section of the outside bearing wall, shown at the bottom of the photo. The opening was too great, causing the entire wall to fail. At the top is a cantilever; the floor below is a supported lean-to pattern; and the bottom two floors are pancaked. Note: The author rescued a trapped victim from underneath the supported lean-to floor section halfway up the floor, and the victim survived.



Fig. 4–23. A major collapse in New York City on October 24, 1988

Void Search Operations

Survival rate versus time of extrication

When your team responds to a structural collapse rescue operation, two questions need to be answered immediately: How many victims are trapped? How long have they been trapped? Below is a chart with some averages on survival rates. These have been drawn from numerous major incidents:

30 minutes	99%
first day	80%
second day	37%
third day	33%
fourth day	19%
fifth day	7%

These numbers are rough averages. However, they give you some idea of the possible survival rates of civilians trapped in collapses. Of course, many factors will come into play at each incident. Weather conditions, type of structure, quality of construction materials and workmanship, mechanism of collapse, available resources, and available rescue personnel are just a few factors that will affect the operation.

When evaluating the situation at a structural collapse incident, some of the factors just mentioned will definitely need to be considered when the operations personnel try to determine the chances of survivability of the remaining victims. We will examine some of the items that make the greatest impact on your decision to make this a rescue operation or a recovery operation. Generally, this is the most difficult decision to be made at any operation.

The five stages of collapse rescue

One of the toughest jobs that you can possibly encounter as a chief officer is a major collapse operation. You may literally have to answer a hundred questions at once, and all your answers are supposed to be right. To ease your operational procedures at these complicated operations, the rescue operation can be broken down into the following broad categories.

Collapse site management. As the rescue opportunities are identified in your collapse structure, it is important that your teams stay disciplined and adhere to the tasks assigned to them. Any freelancing is counterproductive and extremely dangerous.

The initial size-up and preliminary site control activities should occur simultaneously, if possible. The responsibility of the on-site commander is to review the safety issues and the total collapse situation. With this information, the commander can formulate a safe plan for the rescue of trapped victims. While this is being accomplished, the commander's authority should be delegated to local site commanders in several important areas, including the following:

- Assessing and mitigating any possible hazardous materials that the teams may encounter.
- Shutting down any utilities that may be affecting the operation.

- Establishing a collapse danger zone to keep equipment apparatus and personnel out of danger.
- Establishing a defined work zone in close proximity to the collapse danger zone, where the equipment staging area and cutting or workstations should be located.
- Establishing an overall safe zone for nonessential bystanders and other unnecessary personnel.

The following six stages of collapse site management are provided as an outline of the usual procedure for a chief officer.

Stage one. The initial assessment of the collapse area is done at this time. Take some time to determine the extent and severity of the situation before you commit any more forces. Normally, on your arrival the first-in companies will have already committed themselves. Make sure the entire surface area of the collapse zone is searched for any surface or partially buried victims. Their removal will not be an extensive operation requiring shoring or void search operations. Determine immediately what type of structure it is: commercial, residential, retail, public assembly, and so forth. This will give you some idea of the victim potential. What type of collapse is it? It could be localized, extensive, or total. Assess how much debris there is and how unstable it is. Try to identify and control any possible hazards associated with the specific occupancy or structure. Check and evaluate the stability of the remaining structure in order to determine how dangerous it will be for your rescue personnel. All the utilities that are feeding the building must be evaluated for their present danger and turned off accordingly. For safety reasons, all utilities should be shut down immediately. Identify as soon as practical the possible or likely locations where victims may be trapped. Organize your search efforts accordingly. Determine and identify to all personnel the safe access and egress to the remains of the building. Keep all access points monitored by command personnel.

Stage two. The removal of all the possible surface victims that your teams have discovered should be done as quickly and safely as possible. Be aware of possible secondary collapse potential. For the purposes of this stage, anyone you can see or touch would be a surface victim, whether partially or totally buried just under

the surface. If you can reach these victims immediately, they are considered surface victims.

Stage three. Search all voids and accessible areas for live victims who may be trapped. Stay organized during this stage. All void searches must be coordinated with other existing operations. Use the accepted search techniques that your team has trained on: canine, audible, visual, and hi-tech, if available. Your size-up will help prioritize the area to make better risk versus benefit judgments. Rescue would then proceed using existing cavities, duct or plumbing shafts, basements, and/or small cut openings in easily breachable floors and walls. Some shoring may have to be done to provide a safe haven area and otherwise protect emergency responders and the victims. This phase should only be attempted by trained qualified personnel. Any attempt to have this operation done by untrained people can have drastic results. These void search operations will be the most dangerous that your rescue teams will be involved in during the collapse operations.

Stage four. This stage includes selected debris removal. Special tools and equipment may have to be brought in to effectively complete this stage. Information about any possible victim locations should be given to your rescue teams just before this stage starts. Good information will cut down on random searching.

Stage five. The general debris removal stage is normally conducted after all known victims have been accounted for. The use of heavy construction equipment will greatly speed this operation. However, do not use heavy equipment until all victims or possible victims have been accounted for. It would be too easy to drag out a victim with the debris. If all of the victims are not accounted for, you must do this phase in a slow and methodical fashion, removing debris a little at a time and then searching both the debris as well as the area you just uncovered.

Stage six. Taking up from your collapse rescue operation is the last step in collapse operations. Some of the factors to be addressed are determining who is left in charge and recouping tools and materials used or damaged in the incident. Always have your rescue teams critique the operation within a day or two of the incident. Making sure their thoughts are still fresh in their minds, go over the operation and discuss how it went, good or bad. This should be a learning experience only, not a witch hunt. Address issues that went well and issues that did not go well. If something

did not go well, discuss what could have been done and keep it in mind for next time. Last but not least is critical incident stress debriefing. Some rescuers react differently to each stress situation. Signs of stress need to be looked for in all personnel who operated at the scene.

Setting up your collapse zones

In order to ensure a safe and effective collapse rescue operation, the incident commander must maintain full control of the area surrounding the collapse structure. This includes the front, back, both sides, and possibly the top and bottom of the affected building. The establishment of a collapse hazard, hot zone, or secondary collapse area (whatever you wish to call it) must be one of the commander's first priorities. The purpose of this zone is to control access to the immediate area of the collapsed structure. This area may be affected by secondary hazards, including further building collapse, the falling debris, and any other hazard that may develop. The only personnel that should be inside this zone are primary rescuers that are directly involved in search, victim extrication, or shoring operations. All other personnel must be located outside the zone until assigned or specifically needed. The hot zone can be identified by with an X made of tape, flagging, or rope.

An additional rescue work zone should also be established for support personnel only. This safe and secured area is used especially during long-term operations. The rescue work zone can be identified by a single rope, flagging, or tape. All civilians and nonessential personnel should be located outside of this work area. Included in this area should be the following:

The operations post. The officer in command and direct subordinates should be located in the operations post. These will include hazmat, void operations, shoring, rescue medical, and equipment bosses. In an initial first-due operation, the officer in command needs to be here also, to be directly involved in the size-up, evaluating the situation, and commanding the operation.

The medical area. The paramedics and support personnel should be in the medical area. They should be set up to handle victims as well as any injured rescue personnel. An area that is large enough to set up their medical equipment must be provided.

Personnel staging area. A specific area should be set up where all rescue personnel can be either relieved or assigned. Shelter, food, and a rest area should be supplied here during a prolonged operation, which any extensive collapse with multiple victims can easily become.

Shoring work area. The cutting team members can set up their work area and cutting tools in this area. There must also be enough open space for the lumber to be stockpiled and space large enough to give the shoring team an area to prebuild the shoring if necessary.

Equipment staging area. A large enough area must be maintained for the storage and upkeep of all rescue and shoring equipment and tools. A specific area should also be set up for tool maintenance, blade changing, fuel refilling, and so forth. Thus the tools can be continually maintained and rotated. Specific personnel must be assigned here for these tasks and to keep a tool and equipment log. The operation will come to a grinding halt if this is not done.

Safety of rescue personnel. On-site safety precautions taken by the rescue team are a high priority in all operations. The responding personnel must make sure not to engage in any unsafe acts that will result in additional victims. It is a little late to devise some sort of signaling system on-site. Some personnel will be informed, and others will not. This is especially important when dealing with multiagency responses, which most extensive collapse operations entail. Communications in these major operations can always be a problem, so simple procedures should always be set up beforehand. Here is a system that is already in use by the Federal Emergency Management Agency (FEMA) Urban Search-and-Rescue (US&R) teams. For continuity, it is a good idea to use these signals. They can be sounded by an air horn or another appropriate device.

- Evacuate the area: three short blasts, approximately 1-second each.
- Stop operations, have all quiet: one long blast, 3-second duration.
- Resume operations: one long and one short blast.

Grid search techniques. To make search easier in a major collapse operation, one method is to divide up the collapse structure in a grid system. Search each grid methodically and keep an accurate record of the

progress being made. There should be one person in charge of each grid area, which can be defined as a sector for operations control. The person in charge of each sector must give regular reports to the incident commander.

Determining the size of your grids or sectors.

There are several factors involved in determining the size of your grid search operational procedures. Some of the factors to consider are the following:

The size of the structure involved. The biggest problem you will have is keeping your personnel contained and organized. A proper and effective search done safely and quickly is one of the major concerns of the initial operation. In smaller private homes, such as one-story ranches, only two teams may be necessary. In larger homes, more teams may be needed. In larger buildings such as apartment houses, multiple teams may be put to work. The key is to give your teams room to work; don't pile your personnel on top of one another. This is counterproductive, not to mention extremely dangerous.

The amount of structural damage that has occurred. One of the biggest factors in determining the number of personnel to commit to the search operation is the amount of structural damage and debris caused by the collapse. If there is limited damage with light debris in your team's way, then a small number of teams can move about rapidly and cover most of the collapse zone. Remember, the least number of personnel exposed to danger, the safer the operation will be. However, if there is extensive debris and mobility is restricted, more teams may be called for. In this case, the search process might be more difficult, because smaller areas must be examined more thoroughly as a result of the large amount of debris. When this situation occurs, the pace of the rescue teams will be slowed dramatically. It will be more productive if several teams are assigned to the search operation. The teams can be given smaller areas to search, and the operation can progress smoothly without the teams interfering with each other.

The number of possible victims trapped. The number of victims that are unaccounted for is another factor in considering how many rescue teams need to work at the same time. If the decision is made to bring in more teams, then the areas can be broken down into smaller grids. These areas then can be searched much more rapidly by the coordinated efforts of the teams responding.

Natural barriers that have occurred. In every collapse, sections of the building will develop obvious natural barriers. Whether it is a section of the roof protruding out of the rubble or an area of floor lying vertically and separating debris areas (to name only two of many possibilities), there will be some indication of how to divide the structure into manageable grids. You must use these natural barriers to your advantage. It will make the job that much easier and speed the operation to a successful conclusion.

Types of collapse voids. A major priority is determining the types of collapse voids and their locations. This information can then be used to figure out where the best areas to search will be. The search patterns should be immediately set up to check the location of these voids, for these will be our best chances to find most of the trapped victims alive. Therefore, these areas should be searched first.

The number of collapse voids encountered. If there are numerous voids where the possibility exists of live victim recovery, the size of the grids will have to be adjusted accordingly. Due to the extensive amount of searching that will be needed in the tight areas, the grids should be smaller. Conversely, if there are fewer voids to deal with, then most of the work will be removing debris from above. In this case, the grids should be much larger. This will give the teams some more room to work without getting in each other's way.

The number of trained rescue personnel. Unfortunately, the number of teams that you can put in these dangerous search situations may be limited. Untrained personnel should not be used for void search exploration.

Void exploration

At all collapse situations, the safe rescue of trapped victims is the firefighter's primary concern. After extinguishing the fire and removing the surface victims, initiate a systematic search of all collapse voids. This is the most difficult and dangerous component of collapse operations.

Void search-and-rescue team. As safety precautions are being addressed and needed shoring is being erected, a void search-and-rescue team should be established and be put into operation. If the collapse operation is extensive or an entire structure is involved, more than one team may be needed.

The primary function of the void search team is to search any existing natural voids (those that already have been created by the collapse) rather than debris trenching and tunneling, which is an extremely complicated, extensive, and time-consuming operation. These voids will be the fastest and easiest to explore, and most of the victims found alive will be trapped in them.

A specially trained six-member void search team, consisting of one officer and five firefighters, generally works well. The team is split into two subteams, the search team and the support team. The search team consists of the void team officer, the void entry firefighter, and the shoring firefighter. The support team, composed of the void expander firefighter and the support firefighter, will be handling the tools and equipment to search numerous voids and extricate multiple victims.

Debris removal. During void exploration, natural props and supports should be removed only when absolutely necessary. This is when, in the judgment of experienced crew members including the void team officer, it is considered safe to do so. Beams supporting other debris, sections of floors, doors, stairs, and so on, should be left in place if possible. Use all the natural bracing that is present to facilitate your rescue efforts. Shoring structural members is preferred to removing them, since removal significantly diminishes the margin of safety under which void firefighters operate. Increased debris handling makes for less efficient operations. The less material removed, the safer and more efficient the operation will be.

Shoring and bracing. Accessing the void from an alternate route should be considered before deciding to remove elements supporting debris. If, however, lumber supporting a substantial amount of debris must be cut, first it must be properly shored. You must take the time to examine the debris to determine the best method for shoring it. Bracing from more than one direction may be needed.

The shoring and bracing operation can be extremely dangerous and must be performed by highly trained personnel or tragic results may occur. Use the minimum number of people needed to complete the task. Under the direction of the void team officer, firefighters working in the void should be relieved on a continual basis.

Void size-up

To help the void team officer to size up the void situation, a nine-point acronym, FASTVOIDS was developed:

- Fire
- Additional collapse potential
- Structure type and condition
- Trapped occupants
- Void type
- Occupancy type
- Immediate utility shutdown
- Day or night
- Situation that caused collapse

Fire. The threat of fire always exists at any collapse situation. In addition, an explosion is always a possibility in the initial collapse stages, since gas lines or pressurized cylinders may have been ruptured as a result of the collapse. All firefighters should be in full protective gear until all fire and explosion hazards have been fully addressed, which generally is not until the later stages of collapse operations.

Fire spread throughout collapse void spaces will be rapid. Fuel and ignition sources can be located anywhere in the structure. Shorted-out appliances and free-hanging wires can suddenly ignite ruptured gas lines, leaking containers of flammable liquids, or fuel from equipment. A charged hand line must be placed in a protected position prior to void search operations. Firefighters operating at any collapse situation should be on constant alert to the ever-present danger of flash fire.

Additional collapse potential. Secondary collapse is the most unpredictable and dangerous condition at any structural collapse operation. A thorough and ongoing size-up will determine if conditions call for shoring or removing unstable walls or floors before conducting void search, or if void search can be conducted immediately. Each building collapse has its own special problems, which should be addressed as the need arises. In larger buildings with extensive collapse, you may be able to search voids safely in one section of the structure while shoring operations are being conducted in another.

Vibrations must be factored into the size-up for secondary collapse potential. After a building collapses, some structural elements may be hanging by a thread. Train, subway, and street traffic in the immediate vicinity must be rerouted until the entire operation is over. Heavy earth-moving equipment also must cease operating. In a collapse with a large amount of hanging debris, which frequently is the case in multiple floor collapses, even the noise and vibration of some tools may be detrimental to the operation. These tools include gas-powered chain saws, generators, and demolition hammers. For safety reasons, vibrations must be kept to a minimum.

Structure type and condition. An extensive amount of pertinent information can be derived from the structure type and building condition. Is the building new or old? Is it occupied or vacant? Is the building under renovation? Was there previous fire damage? Is it framed or unframed?

An older building usually indicates that structural elements may be fatigued, which increases the possibility of secondary collapse. The exterior masonry elements generally take the most punishment over time. The constant abuse of weather causes the mortar and brick or block to constantly shrink and swell, creating a separation of the mortar and the brick and making the structure unsound. This condition is especially evident when two different types of materials, such as steel and masonry or wood and masonry, are mortared together. Due to the different expansion characteristics of each type of material, the bond will be loosened and unstable.

Older buildings tend to be built with more substantial structural elements, which reduces the chance of a secondary collapse potential. Structures built in the past 30 years are often constructed of lightweight structural members and systems, the result of better engineering standards and newer construction materials. Although good for the builder and fine for the occupant under normal conditions, this technology can be a detriment to firefighters in a collapse or fire operation. Although the debris may be lighter, the collapse itself will occur faster and be more extensive.

Depending on the time of day and type of building, collapse of occupied structures presents the distinct possibility that several victims may be trapped anywhere within the structure. Occupied buildings will be loaded with furniture, appliances, and other

everyday living items, adding greatly to the amount of debris and the number of individual voids where victims may be trapped. Most occupied buildings tend to be well maintained, so sections of the building left standing will have a better chance of remaining structurally stable.

A vacant building, on the other hand, generally will be in disrepair and therefore structurally weaker. After the collapse has occurred, the stability of the rest of the structure will be extremely suspect. It must be watched constantly for any signs of secondary collapse. These buildings have less of a debris problem, because most, if not all, of the furnishings will have been removed. The possibility that victims have been trapped is not as great in a vacant structure as it is in an occupied structure. But unless you have information to the contrary—for example, definitely no children playing in the building, no squatters living in it, and no pedestrians passing by—conduct a thorough search.

The void team officer must check for previous fire damage to the structure. This is very important. The possibility of previous structural damage directly affects the safety of the operating personnel. This damage may be hidden by alteration work undertaken to correct or conceal the damage. Suspect the building's entire structural integrity if a serious fire had occurred in it, and conduct operations accordingly.

Structures under renovation present a unique set of problems. Many collapse situations are the result of unsafe and shoddy alteration work. In multiple dwellings under full renovation and alteration, it is not uncommon for the contractor to breach large holes in bearing walls to achieve better access to the numerous apartments. Renovators have also been known to make a large hole in every floor, each in line with those on other floors, for easy debris removal from the street. Walls and floors often are stripped down to the studs and beams. In short, the cumulative effect of careless renovation work leaves the structure susceptible to collapse under any type of impact load. A wheelbarrow full of debris dumped only the distance of one floor can cause a major collapse—and already has. How the building is constructed determines how it will collapse. In a framed building, the floors and roof are not dependent on the walls for their support. They are hung on a skeleton-like framework, generally consisting of large structural concrete, steel, or heavy timber girders and columns. In a collapse situation, these elements can withstand and transfer loads

applied to them. Usually, a section of the building can collapse while the remaining structure stays intact. In this type of building, collapse can be relatively localized and not nearly as extensive as it would be in an unframed building.

An unframed or wall-bearing structure is one in which the walls support the weight of the floors and roof. Typically, this is the most common type of building you will encounter. Failure of any part of these walls can cause a collapse. If possible, gather all pertinent information before starting search operations. Some of the most important considerations are the location of the last room or area of the building where the missing people were seen, how many people were there, what were they doing, and the clothes they were wearing. If construction or other workers were in the building, ask in which area and on which floor they were last seen and what kinds of tools or equipment they were using. If you find these tools or equipment, the victim may be close by.

Trapped Victim Rescue. Entering voids to search is one thing; when a victim is discovered, another operation will ensue. You must stabilize the void and the void opening and expand the void enough to enter with personnel, tools, and rescue equipment. Victim rescue will be a sustained operation, for the most part, and must be done safely. Check the entire collapse area for victims trapped near the surface. Remove these victims immediately. The next step is a more thorough search. You may choose to use search dogs or some of the new, sophisticated search technologies available today. Remember, however, that the round-the-clock method is very effective and possibly the quickest and easiest searching method. This quick search method was actually developed by the London Fire Brigade during the blitz of London in WWII. Basically, when you arrive at the collapse site, you pick out a specific area that would likely have survivors buried in the debris. Set up your personnel in a circle around the area similar to the numbers on a clock, and have each person shout into the voids in the collapse, listening for any response. If you hear a response, have one of the other personnel also try to make contact and hear where the victim is located. In this way you can pinpoint their exact location in order to start the rescue. This is a quick, simple and low-tech way to get started with your searching.

Void type. The type of void created by the collapse is the single most important factor in determining

the probable location of the trapped victims and in offering the greatest chance of survival. Check these areas first when you do not have specific information on the location of missing occupants. Six basic void types can be created in a typical collapse situation: pancake, supported lean-to, unsupported lean-to, V-shaped, A-frame, and individual. It is not uncommon to find more than one type of collapse void in a single building collapse.

Occupancy type. The occupancy type will indicate how many people may be in the building, how much machinery and equipment may be encountered, and whether possible fire and chemical hazards exist. Knowing the type of occupancy can provide invaluable information for finding trapped occupants and their possible locations. If the building is a business or commercial occupancy, numerous people unknown to each other may have been working or conducting business in the facility, making it difficult to determine the exact location or the total number of occupants in the building at any given time. In incidents involving transient occupancies such as hotels, restaurants, movie theaters, and the like, it is next to impossible to get an accurate head count of trapped victims. Searching this type of occupancy takes considerable time and effort. Numerous individual voids are created by machinery, equipment, and furniture, and every one of these voids must be searched. The possibility of finding yet another victim will have to be considered until the final general debris removal stage is completed. In heavier brick-and-joist constructed buildings, such as factories and lofts, the collapse will cause large amounts of crushing debris with limited void spaces and limited void access.

In residential private dwellings, the collapse voids usually are extensive due to the lightweight construction techniques generally used. Determining the number of occupants in private dwellings should not be too difficult. Begin by checking with neighbors, friends, or relatives in the area to determine if the occupants were home at the time of the collapse and how many people live at the site. When it is uncertain whether the building is occupied, noting the number of cars in the driveway and the presence of toys or bikes outside the building can provide clues. Determining the number of occupants in multifamily occupancies is more difficult, but it can be done with some accuracy. Check the number of mailboxes. Get a list of tenants from the building superintendent,

who can tell you which apartments are occupied, how many tenants are in each apartment, and tenants' general work schedules.

Immediate utility shutdown. One of the first actions you should take at any collapse operation is to make sure all utilities supplied to a building are shut down as soon as possible. Shut the gas down first, because it is the most dangerous and could easily ignite, causing a fire or explosion. The possibility of asphyxiation also exists. Shut down the electricity, since live wires present an electrocution and fire hazard. Firefighters coming into contact with charged metal objects could be shocked or electrocuted. A spark created by firefighter's tools contacting these wires could cause a fire or an explosion.

Water must be shut down. Leaking water pipes add substantial weight to rubble and make debris removal extremely difficult. It also is possible that someone trapped in the basement may drown. In addition, water accumulation can contribute greatly to the possibility of electrocution. Water may also undermine a foundation and increase the chance of a secondary collapse. Check the atmosphere. For victims' and rescuers' safety, monitor all gases. Before entering any voids, make sure that oxygen is in the accepted range. If not, deal with the problem immediately. For example, insert a hose hooked up to an air compressor into the void, to bring in fresh air. Consider using SCBA. Check for hazardous gases, especially carbon monoxide. Pockets of this gas may have accumulated in low areas. Check the void with an explosive meter before rescuers enter. For maximum safety, monitor the gases during the entire operation.

Day or night. The time of day or night a collapse occurs affects the number and locations of possible trapped victims. For example, if a collapse occurs in a residential building during the night, the victims will tend to be in bedrooms and usually be limited to family members. Interviews with survivors should make it easier to determine the number of missing occupants. When a collapse occurs during the daylight hours, however, it may be much more difficult to determine if occupants are home. Immediately interview any eyewitnesses. Also consider that neighbors may have been visiting or other children may have been playing in the area.

It is likely that only a few people are in commercial occupancies at night. However, check these structures for security and maintenance personnel any time

of the day or night, and don't forget that some facilities have night shifts. At night fewer hazards may be present inside a building, since much of the machinery will be shut down, and equipment and stock generally will be put away. During working hours, most machinery will be activated, and people, stock, and equipment can be found anywhere in the facility. In such a situation, it is difficult to determine the number of missing occupants.

Situation that caused collapse. The reason the collapse occurred can also give you valuable information about where to look for victims, what type of damage occurred to the structure, how extensive the damage may be, and possibly what type of safety problems you may encounter. This is probably the most important single factor to look at during a major structural collapse operation. It is imperative that you determine what caused the building to come down as soon as possible. The cause of the collapse is of major importance to almost all facets of the operation. You need to know the amount of force that was applied to the structure as well as the people in the structure. There is an obvious correlation involved with this situation. For example, if an explosion occurred in a structure strong enough to destroy it, then anyone inside would be subjected to the same force. Unfortunately, the human body is far more fragile than the structures we inhabit. If a building has had enough force applied to it to destroy it (e.g., by an explosion), the chances are greatly diminished that there will be many survivable victims. Of course, many factors come into play here: the extent of the explosion, the force or speed of the explosion, how much of the structure has come down, how much has stood up, if there are areas in the building that could have blocked the force of the explosion, and the like. This is all useful information in determining whether it is likely that anyone survived the collapse.

Initial void entry

Entering the void. These are some of the key points you and your rescue team should consider before and as you enter a newly found void space. Some of these items are the type of floor construction, moving of loose debris, examination of structural supports, conditions under the void, stability, condition of utilities, the type of void, and your team's exact location. Remember that collapse rescue is a careful, methodical operation, and safety is a paramount

concern. The rescue effort must be undertaken with care—any sudden movement of the elements in the void may injure rescuers and victims alike.

Type of floor construction. Knowing how the floor is constructed can give you some important clues to safely guide you through the rescue operation. Knowing how it is fabricated can tell you how to shore it up properly or stabilize it if it has sustained any structural damage. The way it is built will also tell you how much weight it will possibly support or how and where it could fail in a secondary collapse situation. Therefore, all of the members of your rescue team must be thoroughly familiar with the common types of building construction in your response area.

Moving loose debris. Before entering the void, make sure the mouth of the void is large enough for easy access and quick egress if necessary. Depending on the operations around the void or the threat of secondary collapse, the ability of the void entry firefighter to leave the area quickly must be a high priority. Move all loose debris from around the opening, which will increase the size of the opening and help define which elements of the structure are still supporting anything or if they can be removed. Loose debris only creates dust and makes maneuvering difficult. The rescue firefighters can easily slip on the loose material and may become injured. The safety of the rescue operating personnel should be of paramount concern.

Structural supports. One of the first steps the team must do is to check all the larger structural supports that are located by the void area. Any beams, columns, joists, or girders must be checked for their present condition. Determine whether they are cracked, broken, or twisted. Try to ascertain what, if anything, they are supporting. Also check to see what is supporting them; a collapse can cause the whole structure to be unstable, and by resupporting some of these damaged or loose elements, some structural integrity may be regained. They must be secured before you do any work in the void, given that they are still an integral part of the support structure.

Conditions under the void. Examine the area directly underneath any voids you will be operating in to determine stability. For any operations to be conducted, whether extensive or not, the area must be stable. If a firefighter enters a void, and the material cannot hold the firefighter's body weight, the results could be disastrous. The entire void could collapse, burying the firefighter and any victims in the

void. This would most certainly trigger a secondary collapse, the worst situation you can have. A secondary collapse can affect the entire structure, because loads that were being held precariously in other areas will be violently shifted. This could result in the development of a very dangerous situation, with many of the rescue personnel severely injured or worse. For this reason, careful examination of the area underneath the void must be done before entering the void.

Stability of area. As you expose your void entrance, and before your firefighters enter the void for search, a few minutes should be taken to examine the stability of the area you are about to enter. Visually check the void area for stability and the possibility of any hanging debris, cracked or broken supporting beams, and any unstable sections of flooring. It also is a good idea to probe the area ahead of you before you place all your weight on it. Remember, there may not be a lot holding it up.

Utilities. Before the void is penetrated, you need to check for and observe if any gas lines, electric cables or conduits, telephone or computer lines, or any other type of utility-carrying device is hanging in your way. Make sure they are not in the way; if they are, make sure they are properly secured. Avoid handling any utilities and, as a safety precaution, always treat them as if they were alive. Have the officer make sure that the utilities have been properly deactivated to the entire building. This is a must.

Type of void. As soon as possible you must determine the type of void the team is entering. Each void type has its own danger areas and probable victim locations. The team members should concentrate on these areas they start operating in void spaces. As each void is identified, the specific danger areas can be examined and possible shoring operations begun.

Your location. Try to get your bearings and determine exactly where in the structure you are actually located. Sometimes it is very difficult to determine what room or area you are operating in or what floor the team is on. As information about the locations of trapped victims is relayed to the rescue teams, knowing where exactly you are located will make searching for possible survivors much easier. The team will be able to navigate the structure much more quickly.

Weather conditions. In any operation, the weather can have a tremendous effect on any operation. Extreme conditions will drastically affect the

rescue effort, the rescuers, and any possible survivors. In many cases, bad weather will cause the rescue effort to be inordinately slowed down. Temperatures that are below freezing for an extended period of time will take a severe toll on the efficiency of the rescuers as well as most of the equipment. Temperature extremes will affect victims trapped near the surface more than those trapped in a basement or an underground area that has some protection. Because their bodies' core temperature will decrease and their metabolism may start to shut down, their chances of surviving will rapidly diminish as time goes on. On the other hand, warmer weather is more beneficial for trapped persons. If the weather is too hot, though, it will also cause the rescue effort to slow down, creating delays for the extrication of trapped victims. In warmer weather, there is also the chance of infections developing more rapidly in injured victims.

Type of structure. The number and type of survival voids that will be created in a collapse are largely determined by the type of structure. Larger voids and more voids increase the chances that victims will survive the collapse. In lighter weight structures, such as wood frame, lightweight steel, and smaller URM, there is a good chance of finding numerous large voids. In this case, extensive void search operations should be conducted as soon as safety permits. The team's chances of finding survivable victims are extremely good. In the opposite case, when the collapse occurs in a much heavier type of structure, such as all concrete or steel and concrete, the odds of finding survivable voids are greatly diminished. The building's structural elements themselves are much heavier weight, and the floors are much denser and larger. This additional weight, when applied as an impact load on the lower floors, will cause them to fail more rapidly. As a result, the survivable void areas will not be plentiful, lowering the chances of victims surviving. However, this doesn't mean there are no live victims left in the structure. There is always that possibility, which has been proven to us time and time again.

Quality of construction. The main issue here is twofold: the quality of the building materials and the building techniques used to fabricate the structure. In the former, especially in developing countries, the quality can be very substandard. In this case, when a collapse occurs, the structural elements will literally crumble and fall apart. In a building that was poorly erected, several problems can arise in a collapse situation. The most common is that the building's

connection points will be inadequate to support any additional strains or forces. The structure will fall apart due to its inability to properly support itself. This will leave few void areas in which to search. Another problem here is the unstable structure that remains after the initial collapse: There is a serious potential for secondary collapse because of the substandard building materials and techniques. All of these conditions create major safety problems when attempting a rescue operation.

Mechanism of collapse. We also need to know whether the mechanism that caused the collapse is still active. It may still exist even after the building has collapsed. A gas leak that blew up a building may still be active and could cause another explosion and secondary collapse. Earthquakes have numerous aftershocks, several almost as strong as the initial event. This could easily bring down many damaged structures.

Consider an incident where half the building is on the ground and the other half is still standing. What caused the first half to come down? Why isn't the second half down? Finally, what is stopping the second half from suddenly collapsing while you are operating?

Important Safety Factors

Movement

Any type of movement is an imminent sign of collapse. You must be constantly watching the remains of the structure for any signs of movement. The potential for secondary collapse is present at every structural collapse.

Cutting through existing floors to gain access

If there are no obvious openings between floors or there is no easy access to the lower floors, then your next option would be to open up the floor you are on to gain access to other floors. Stay away from cutting beams or floor joists if you can. Whether they are broken, out of place, or dislodged, they may still be supporting material. Cutting them may cause a secondary collapse. The easiest and safest choice is to cut through the floor itself (figs. 4-24, 4-25, and 4-26).

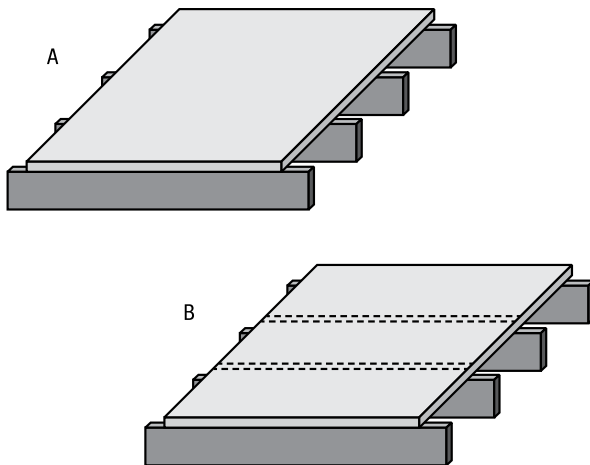


Fig. 4-24. (A) Check the floor. Determine what it consists of: tile, carpet, oak flooring, and the like. You need to get to the subfloor, which could be plywood or 1 × 6 pine or spruce for older buildings. Get down to the subfloor, and cut the finish floor if you have to. (B) At the subfloor, cut a pilot hole. A triangle about 12 inches for each leg works fine; you should be able to see what's under you and possibly what's around under the floor. Do not cut too deeply! Just cut the floor—remember, there could be debris or victims under your location. Determine where the joists are. Depending on the accessibility to that lower area, you may or may not have to shift your location.

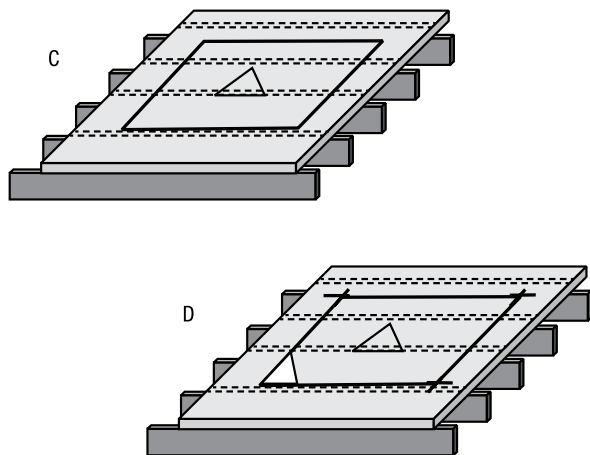


Fig. 4-25. (C) Next size up what's under you and where you want to go. Remove the existing flooring if necessary or cut through it if you can. Remember that most of the time it is more effective to remove the finished floor first. These floors play havoc with saw blades, dulling them rapidly. Lay out a good-sized opening that is not too big, but make sure it is big enough to fit a Stokes basket, personnel, and tools through. Keep the two ends of the opening close to the floor joists, which makes the opening easier to cut. Also, it will have less bounce, and it will not have a large edge to get hung up on. (D) Cut a hole in one corner, which will make it much easier to grab the cut section and pull it up when your cut is finished. Remember, to cut the subfloor, all your blade has to do is penetrate the depth of the blade's teeth, roughly 1/4 inch. Overlap your corner cuts in order to make sure the corners are fully cut.

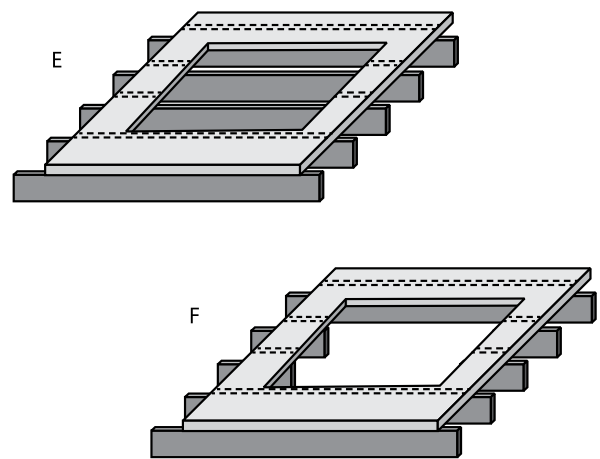


Fig. 4-26. (E) After you have cut the section fully, pull it up. Do not drop it into the hole in pieces, you may hit someone you cannot see. Look down and completely examine all the area you can see, evaluate your position, and look for possible victims. Check for stability and what's holding what up structurally. (F) Cut the floor beams out as long as it is safe to do so. Cut them flush with the floor opening, because you do not want anything hanging up on the end of the cut beams while you are lowering yourself into or getting out of the hole. You are now ready to conduct operations in the area below this floor section.

Tools possibly needed for void search and rescue operations:

- Hand tools: Utility knife, wire cutters or pliers, prying tool (to free objects that are in your way).
- Sawzall®: Battery powered to start with; bring extra batteries.
- Power nailers: If doing any shoring inside the void, bring this tool.
- Air bags: To rescue victims who are pinned; use small bags.
- Air chisels: To cut through appliances or sheet metal.
- Search tools: Helpful during long-term operations, including search cams and a search and rescue video system such as SnakeEye™, used to probe small openings.
- Listening devices: Only work well after initial operations have calmed down. Otherwise too much interference.
- Hot stick: Detects electricity in cables that are not shielded.

- Bottle jacks: Can work well for lifting lumber or beams off of a victim, not to be used for shoring.
- Lighting: Flashlights, helmet lights, portable lights, and flood lights.
- Air monitoring: Meters.
- Safety items: PASS (personal alert safety system), gloves, eye protection, uniform protection, foot protection, and respiratory protection.

Shoring Operations: An Overview

Introduction

Although rescue shoring operations can be vital to any collapse operation, there are times when it is not necessary. For example, there was no rescue shoring installed at the World Trade Center. Shoring was installed by the contractors to stabilize the existing floors in order to rebuild. Nothing was installed as a rescue mode. Many lighter frame structures, such as condos and private homes, may not need shoring. If they are heavily damaged, such as in a gas explosion, the buildings may be completely collapsed and in numerous pieces. In that case, it is easier to start at the top and remove the lightweight sections, and then do the void searching from there, negating the need for rescue shoring. However, if the need arises for rescue shoring, then follow accepted guidelines for the installation of rescue shoring systems.

Emergency Rescue Shoring

Emergency shoring operations for urban search and rescue incidents are defined as the temporary stabilization or resupport of any part of or section of a structural element that is physically damaged or missing, or where the structure is partially or totally collapsed or in danger of collapsing. Shoring is done to provide a safe and efficient area while conducting search and rescue operations for trapped victims. After shoring up a structure, searches will be safer and present lower risk to both the victims and the rescue forces. Adjacent structures and object that may have been affected by the initial incident should also be shored up.

Shoring may be a temporary support, but do not remove it until more permanent shoring has been installed. This is comparable to not just pulling out pneumatic struts at the end of the operation without replacing them with wood.



The objectives of rescue shoring operations

The paramount objective of installing emergency building shoring is to maintain the strength and integrity of the structurally damaged or unstable elements. These elements include but are not limited to beams, joists, girders, columns, arches, headers, and bearing walls.

Properly installed rescue shoring receives and transmits (or redirects) unstable collapse loads. These loads often form in specific areas, causing a heavy concentrated load effect. The loads of these overstressed structural elements must be ultimately transferred to stable ground. Many times, depending on the type of structure, these loads can be transferred or redirected to structural elements in the remaining parts of the building that are sound and capable of handling additional collapse loads.

Basic rescue shoring points

Emergency shoring must be erected as a complete system. Unlike what is generally done in the construction industry, emergency building shores must be constructed as a complete system. Tying all the shores together increases the stability as well as the efficiency of all the shores. The possibility of secondary collapse is the biggest problem at any structural collapse rescue operation. In order to accomplish this safely, all the shores must be assembled together as a complete unit.

Lateral bracing must be installed to prevent system from buckling. It is very important to laterally brace all the shores in both directions. The shores must be able to withstand lateral pressures that may be applied to the shoring system from any direction. Sudden shifts can easily occur in unstable collapsed structures, thus applying eccentric and or torsional loading.

The minimum level of lateral strength in vertical support is 2%. However, 10% is more desirable. Rescue shoring differs from typical contractor installed shoring in that contractor shoring is generally a friction type. This type of shoring relies on the pressure of the shore against the damaged material for it to stay in position. A major problem with friction-type shores is that they have very little lateral stability and can be easily vibrated or knocked loose, something

we cannot tolerate in an emergency situation. The potential for secondary collapse is always present in structural collapse rescue operations. We must be always prepared for it.

In rescue situations, we must have fixed shoring systems installed because of the dangerous possibility of secondary collapse. These types of shores will stand up to that threat much better than friction types. Rescue shoring must be a complete system to properly resist forces from several directions. As already stated, this can only be done with lateral bracing applied to the shores, tying all the shoring elements together.

Shoring system

For a shore to work properly and be considered a system, in general it must have four parts: a header or top plate, one or more posts or struts, a bottom or soleplate, and a lateral or diagonal bracing system. Each one of these parts is important for the success of the shoring system. The key to all the shores is to collect the loads from a damaged area, funnel the loads through the post system, and redistribute the loads to the ground or other suitable structural elements.

Considerations when starting a shoring operation

When responding to structural collapse operations, many things should be running through your mind: possible victims, fire problems, exposure problems, how extensive the collapse is, and what caused the collapse, to name a few. If you make the decision to have your rescue personnel enter the remains of the collapsed building, then the safety of your personnel must be paramount. Having rescuers become part of the problem instead of the solution is not acceptable. One of your main concerns is the stability of the remains of the structure. To stabilize the structure for the protection of both the victims and the rescue personnel, rescue shoring operations must be considered.

There are three options to help you decide whether to start shoring: avoid, mitigate, or shore.

Avoid. In collapse situations, especially in larger structures, victims may be trapped in only one immediate area. There will be times when an area that is unstable is not in the area where rescue personnel

will be operating. If this is the case, the area can be avoided by blocking it off and keeping all personnel out of the danger zone. This would negate the necessity of having to attempt an extensive shoring operation. If this is the case, make sure that the area to be avoided is properly marked off and safety officers have the access blocked or continuously watched. The area that has been marked off should also be continuously evaluated by the structural engineers for any change in stability as a safety measure.

Mitigate. Often a situation will arise in which we must work in or near an unstable area that we cannot shore. The only option may be to mitigate it by removing the hazard. For example, when dealing with masonry walls or chimneys, generally it is easier to mitigate than to shore. This is especially true when the bond from the mortar and the bricks or blocks has separated from the joints and cracks. Shoring these unstable walls would take quite a bit of work, and when you start putting pressure and undue forces on the wall, it cracks and the wall becomes even more unstable, risking secondary collapse. Generally, it is much more efficient, safer, and less time consuming to mitigate the problem by taking the wall down than to try to shore it up. Ideally, demolition is an option; but if it is not, then shore up the wall, but be extremely careful not to disturb what remains of wall or chimney.

Shore. If you decide to shore up the structure, the first and foremost consideration is this: Do we have the capability to accomplish this task? To answer that, ask the following: Do our personnel have the training and expertise to accomplish the mission? Do we have the equipment necessary to do the work? Do we have the materials to accomplish the task at hand?

In order to answer the first question, look at the type of training your rescue team does on a regular basis. How much technical training do they really do? Is it geared toward collapse, high-angle rope maneuvers, confined space, trench rescue, or all four? Although many teams have some basic knowledge of and training in structural collapse operations, most of the time they do not have extensive training in collapse rescue shoring. It costs money to put on this type of training, and frankly, it is not a skill used on a regular basis. Many departments do not like to spend money on training like this. Unfortunately, without the proper training in this discipline, your team will have problems erecting safe and effective rescue shoring. If the team has taken some shoring training but has

not kept up the skills, getting involved with a difficult shoring operation may be a dangerous move. This is one rescue discipline that you must have the proper amount of training for and confidence in before attempting, or someone can get seriously hurt. Most of the basic shoring classes available give you some of the overall basic techniques. However, in addition to training, experience is vital to any shoring operations. When you get involved in heavily damaged areas on actual sites, for example, none of the structural elements are square, of course, and the shores must be adapted to the environment. This is where experience and thorough knowledge of shoring types and techniques come in. Knowing what will and will not work for various scenarios is a must. This is absolutely necessary to keep the safety of the operation on your side—the welfare of your team members as well as any victims is at stake.

Monitor. If your team's decision is to shore up the remains of the structure for either rescue or safety when searching the collapsed structure, keep a close eye on any possible movement of the structure. As your team prepares to erect the shores in the building, make up an evacuation plan and set up a warning system known to all in case the structure shifts and firefighters need to be rapidly evacuated. Make sure the removal route and warning signals are plain and known by all of the rescuers on the scene, not just your firefighters. To monitor movement with any kind of accuracy, you need a transit or a theodolite (an advanced transit). Most of the time you will need more than one. Pick the most unstable areas, or the larger floor or wall sections that may shift on you, and line up your sights on those items. Notify the incident commander or the operations chief of any shifting or movement of those sections. Not all movement will be a problem, but continual movement is definitely an issue. Rescue efforts should be put on hold until the determination of the moving area has been established and all safety concerns have been addressed.

Concentrated versus distributed

The main objective of rescue shoring is to take the concentrated overload from debris and redirect or redistribute it to structural elements that will support the load. In a collapse situation, many times an overload condition on the structure may occur. This happens when the building's contents and structural elements have collapsed onto a lower floor. Depending

on the type of collapse voids created, the upper-floor loads will be directed into a specific area. The common patterns are cantilever, supported lean-to, V-shape, and A-frame. The material from the floors above is directed into specific areas in these patterns. That material, which in its normal state and position was an evenly distributed load, has now come to rest on a lower floor in a concentrated form. In essence, the structure's supporting elements are being overloaded because this concentrated load is now being supported by only a few elements, generally floor joists or a girder, or both.

The job of the rescue shoring officer and the structural specialist is to determine this overload and how to redistribute it to either the ground or other structural elements able to support it. This is generally done through some type of rescue shoring. There are several options available, but two are commonly used: The first option is to take the load and directly feed it to the ground or a lower floor, typically done with vertical shores. The other is to transfer the load laterally to the exterior bearing walls.

Missing or damaged structural supports

Beams, columns, girders, and arches are all primary structural elements that support other structural elements. These items must be checked as soon as possible. The building elements they had been supporting may be under substantial additional stresses, possibly ready to fail at any time. Shoring these items will immediately resupport sections of floors that may be compromised in some fashion. It is much easier to replace or restabilize one item than to erect several shores. Generally, these are the first items you should be looking at as you start your shoring size-up. Your team must be skilled in building construction identification in order to be able quickly to identify these particular structural supporting elements. Normally, the quickest way to safely resupport a damaged structure is to concentrate on these elements and properly identify what they are supporting.

Structural fire damage

Has the building sustained any previous fire damage? The structural stability of an area previously involved in fire must be considered suspect at best.

When a structure has totally or partially collapsed due to a fire, safe operation in the structure will depend upon how badly damaged or compromised the remaining structural supports are. Check for fire damage on the ends of the beams where their support will be, and look for any alligatoring (large cracks in the surface or finish that resemble alligator skin) of the lumber. This is a sure sign of loss of structural integrity of that lumber. You may have to shore throughout the damaged area. If you can, keep the equipment and personnel to a minimum in these areas.

Age of the structures

The building's age is another factor in a shoring size-up. The shrinkage and expansion of structural elements due to wet-dry cycles over time result in the loss of strength and the loosening of important hangers and connecting supports. If they have not been properly maintained, building elements such as wood and masonry may have dried out and become brittle and weaker with age. Older structures tend to be built with much larger dimensional lumber than that in use today. This is a definite plus when it comes to collapses and fires. (The danger in older buildings lies in the construction techniques of the times when they were built, when engineering was not as exacting.)

Larger material than necessary was used for safety reasons because of the possibility of mistakes being made in the erection of and the fabrication of those materials. As a result, older structures have what is known as redundancy in their construction. Basically, this means that the structural elements in question could support much more than they were required to. So when a catastrophic incident attacks the structure, these elements tend to hold up much better than a newer, better engineered building.

Structure condition

The overall condition of a structure is another important part of size-up. The shape of the building has an impact on how much damage will occur, how much of the structure will remain intact, and what condition that remaining section will be in. If the structure is vacant and in a state of disrepair, then most likely the critical structural element connections in the building have been compromised. This is generally because most of the joints are butted together at specific ends, leaving more surface area of those elements exposed

to the weather. This usually results in these sections deteriorating first and thus failing first. A structure that has received proper, continual maintenance and repair has a better chance of sustaining or surviving a collapse than a building that has fallen into a state of disrepair. The supporting elements of a well-maintained building may be used to help support and transfer the collapse load throughout the structure. However, if the building's condition is suspect, for example if it is vacant, do not assume that there is sufficient structural support without first inspecting the building. The possibility of a secondary collapse in deteriorated buildings is a primary consideration.

Six-sided approach

The top, the bottom, and all four sides of the structure and the area you are working in (or about to start some type of shoring operation in) must be examined. To start a shoring operation, check what items or sections you will be shoring, then determine their approximate weight. It is extremely important to survey the top of the structure to identify loose, shifting, or hanging debris or structural elements. These items may have to be moved, shored, or completely avoided, depending on the situation. The decisions you make regarding these items will affect your rescue operation. After this has been calculated, then determine if the floor you are on will be able to hold that load. If it cannot, then you will have to look at the floors under the area in question. It may take several floors to hold the weight. Even in smaller structures, you may have to go directly to the basement for your initial support. Remember, gravity is constantly working to pull the building's remains to the earth, so from a shoring standpoint, the bottom survey is extremely crucial. It should be performed simultaneously with the top survey, if possible.

Walls out of plumb

Determine the building's stability immediately upon arrival. Examine the walls in the collapse area. Are they stable, or are they leaning in one direction or another? If they are partition or nonbearing walls, will they affect collapse operations in any way? If they are leaning or otherwise show signs of affecting operations, they must be shored. Walls are designed to accept the loads in an axial position. If the a wall is out of plumb (level in the vertical position), then chances

are very good that it will be loaded eccentrically. This may cause it to be overloaded in one area or become unbalanced, both of which may lead to a collapse. Another issue is that floor beams generally only sit on top of these bearing walls by a few inches. When one of these walls shifts out of plumb only 2 or 3 inches, the remaining bearing of the floor joists may not be enough to keep the floor intact. If you can see a wall leaning with the naked eye, measure how many inches of the floor beams are remaining on that wall.

Strained structural elements

Floor beams and other structural supporting elements under the main debris pile or a victim's location are among the top priorities of site assessment. Older, more substantial beams can withstand large amounts of stress. However, when they are stressed to the limit, very little weight is needed for them to reach their failure point. Severely belled, stressed, or cracked beams must be shored up before rescue personnel are committed to the operation. Examine all of the structural elements that are affected by the collapse, and look for any deflection in them. If they are strained, they must be resupported as soon as possible. When they have been strained they lose quite a bit of their strength, and this must be addressed immediately. Beams that are stressed will go back into shape and still have their strength. Beams that have been strained will not go back into their shape after the load is removed. Their strength has been compromised; however, it is very difficult to determine this on scene.

Type of construction material

The type of construction materials of the building's structural elements has a great deal to do with what size and how much shoring material may be needed. If the building is made of unreinforced masonry (URM), one size will be needed; if it is of steel or concrete, then heavier shoring material will be needed. Typically, the two items that will determine the size and strength of rescue shoring are the weight of the building materials and the weight of the materials and items inside the structure. For this reason, as soon as possible in your size-up, you need to determine the type of structure and the size and type of building materials. Knowing the size and weight of the structural material will give you a pretty good idea of what size shoring material

you will need. The bigger and heavier your structural elements are, the bigger and heavier your shoring material should be. The other aspect to consider is how much weight the building is holding up with its contents. For this reason, the type of occupancy of the building must be determined as quickly as possible. A major collapse potential arises from the overload of materials and contents of a structure. This has to be taken into account when determining the size of the rescue shoring material. Know the weights of the most common building materials and the strengths of the shoring materials you will be using to stabilize the structure. To be safe, the strength of the shoring materials must surpass the weight of the materials to be stabilized. Wood and light masonry may need 4 × 4 lumber and concrete and steel may need 6 × 6 or larger, depending on the size of the structure.

Types of beams

The types of beams commonly in use today are the simple, continuous, cantilever propped, and fixed beams. Each type is supported in a particular way. When the support points for these beams are compromised, they must be immediately evaluated and resupported. Being able to quickly identify which type of beam it is will make it much easier to find the critical support points for that beam and replace or resupport them if necessary. Thorough knowledge of building elements and how beams function are imperative. You must be able to determine how the beams are actually loaded versus how the beams are supposed to be loaded properly. The stress and strain on the beams, as well as the compression and tension, have to be analyzed. The relief of the overloads and the redirection of these loads should be the primary concerns for supporting these beams. These actions will help stabilize the remains of the structure.

Floor construction type

Again, the type and size of the construction material that the floor is made of will determine the size and amount of shoring lumber and systems that will be needed to safely support the damage. If the floor beams are spaced 12, 16, or 24 inches (or more) on center, your shoring material must be spaced accordingly. The size of the floor beams (2- or 4-inch or thicker), bar joists, and trusses, as well as the type of materials used (e.g., concrete, steel), will all deter-

mine the size of the shoring lumber needed for proper support. The type of flooring itself will also be part of the equation. The makeup of the floor and its thickness will be, for our purposes, the main determining factors of its weight. The weight of wood flooring is relatively easy to determine; basically, it will depend on the thickness of the floor. The general rule is that wood-flooring systems weigh approximately 25 to 35 pounds per square foot. Concrete or concrete and steel floor systems are more complicated. The weights of concrete floors vary with the thickness of the floor, the type of concrete, and the amount and size of reinforcing steel that is in the concrete. This can be determined by using the structural drawings of the building or by closely examining the floor sections themselves.

Proper beam connections. Another important size-up point is to check all the beam joints and connections as soon as possible. After the stress and strain of a structural collapse, all the connections in the affected area must be examined and checked for continuity. The physical connections themselves and their supports also must be checked. Items to look for are the stability of the supports and how the beams are anchored to those supports. Examining these items will not take a major effort and must be done as soon as possible. This is one of the first items that must be checked for the safety of the rescue forces. Do not ever forget to do this.

Door and window access

At most structural collapses, access to the structure will be hampered by debris and possibly dangerous materials hanging from the building. Many times your access will be limited to windows or side and back doors, which may limit your shoring team's access for tools and materials. Anytime you use an existing opening as an access or egress way, it must be closely examined for structural defects and instability problems. These must be checked and dealt with before your rescue teams can use those entrances safely. Some mitigation of hazards may have to be done, or some shoring may have to be erected. When utilizing these areas as access ways, you must constantly keep an eye on their stability throughout the entire operation.

Door and window frames out of square

Out-of-square door or window frames tell you that major movement has occurred in the structure. Causes of this include racking of one or more walls in the structure and major wall or possible foundation failure. Whatever the reason, corrective action must be taken immediately. Generally, stabilization of the walls and large sections of the affected floors will help. However, remember that each collapse is different, and the exact cause of the problem should be known in order to correct the situation. Because windows and doors are openings in the wall sections and are therefore the weakest parts of the wall, movement will occur here first. By placing bracing and shoring in the opening, you will be able to restabilize the weak areas. Diagonal bracing has been used successfully to help prevent the structure from racking any further. This should be one of the first options you consider. Also, doors swinging open or closed indicate building movement, and any movement is an imminent sign of structural collapse. This means that the structure has drastically shifted or settled and that some sort of structural element has or will fail in a very short time. If you see swinging doors, your rescue teams should exit the building right away and reevaluate the stability of the structure before entering again to perform rescue or shoring operations.

Sagging floors and roofs

Sagging can occur frequently due to overloading of the floors or roof from any number of sources. Roofs will normally be overloaded by either weather conditions, such as snow or ice, or large objects such as water tanks; heating, ventilation, and air-conditioning (HVAC) equipment; and the like. The size-up must include examining all areas in and around the collapsed structure as well as other areas around the structure that may affect it. Generally, the floors will be sagging from the weight of collapse debris and furnishings. When the floors are sagging, it means that the beams are excessively overloaded, which can cause a further collapse at any time. These beams must be shored up, and the debris should be removed from the floors if practicable. In many cases the multipost vertical shore works well for this.

Columns out of plumb

Generally, columns support beams and/or other columns. If for any reason they are out of plumb, their efficiency and capacity is diminished. The further out of plumb they are, the less efficient they become. Often the columns will be under the joint of a girder or a set of beams. If this is the case, it is important that the column remains plumb. Typically, in this situation there will only be a few inches of beam bearing on the columns. If the column gets knocked out of plumb, then the bearing of one or both of the beams will be compromised, possibly causing a structural collapse.

It is equally important to examine the columns to determine if there is any belly or deflection present. This will also drastically diminish the strength and stability of a column. The items they are still supporting must be secured, and you may have to shore up around the entire column. Check these items as soon as possible. The longer and thinner the column, the faster and easier it will deflect, causing structural problems to occur rapidly. Columns that are still holding up with no deflection, but are damaged, must be watched extensively. The damaged areas compromise the strength of the column and thus will be the first place the column will fail.

Framed or unframed structure

Being able to rapidly determine if the structure is framed or unframed will tell you the general framing of the structure. Which elements are load bearing or non-load bearing is information that you must know in order to properly size up for additional collapse potential and shoring operations. In a framed structure, a skeletal system supports the building and the walls. Collapses are generally a little more localized and less extensive than in an unframed structure. In an unframed structure, the exterior walls are the bearing walls for the structure. If a lower section of one of these walls fails, then everything above may collapse. In the collapse of a unframed structure, the damage may be more extensive than that in a framed structure.

Access to the structure

Access to the entire structure may be extremely difficult due to massive debris build-up or the danger of the remaining structure falling on your rescue forces. Access has to be evaluated before operations

start in order to bring in tools, lumber, and equipment for the safe removal of trapped victims or the purpose of rescue shoring. Often, the primary access, usually the front door, is blocked with debris or too heavily damaged to use. If this is the case, then the safest and easiest point of access should be used. The initial point of entry is generally through the front of the structure. However, if that is not accessible, you may have to change the staging area for all your equipment. Getting the materials you need closer to the point of use is a priority for your rescue forces.

Bulging walls

Identifying any bulging or heavily damaged walls is very important. If they are bearing walls, they may be compromised and can fail at any moment. You must determine the total extent of the damage and area of the wall is bulged. As with any structural component, if it is not loaded through its axis, it can become unstable. Masonry walls are especially susceptible to instability due to the nature of the material. Visible bulges in interior or exterior walls must be addressed immediately. The main shoring operation in this instance is the shoring or stabilization of the floors that these walls are supporting. Normally, that would entail the erection of vertical shores under the floor beams, effectively replacing the damaged wall. With exterior walls, raker shoring may have to be erected in order to stabilize the wall section itself. This will keep the bulging wall from falling and causing a secondary collapse.

Cracked walls

Cracks in masonry walls can be a sign of foundation failure and wall compromise. Examine the cracks for the extent of the damage. However, cracks in masonry walls do not necessarily mean that the wall is structurally compromised enough to fail. If, for example, for a wall that is 10 ft high and 30 ft long with a hairline crack that is, say, 3 ft long, this is not a structural integrity problem. Small cracks like this are not uncommon in masonry construction. However, if there is a much larger crack that has opened a space in the masonry, the integrity of the wall may be compromised. Other clues to serious problems are the traveling crack and the X type crack. The X crack tells you that there is movement in two separate direc-

tions, a definite problem. Try to find the source of that damage and work accordingly.

Separating walls

Walls will separate when the building starts to twist. Checking the joints at the corners can quickly tell you if major movement has occurred. As the structure starts to crack, the interior walls will begin to pull apart. Most of the time this will be easy to spot. Normally, you will see the tops of the corners of the walls peeling apart. As you enter the room, look at the corners from the doorway to pick that out right away.

Vibration potential

There is the potential of secondary collapse due to some source of vibration. By eliminating these vibration sources and checking all joints, connections, and precariously hanging structural members, you can start to make the collapse area a little safer to operate in. Remember, everything we do as a rescue service has the potential to cause some sort of vibration to occur. Every tool we have in our collapse rescue arsenal causes vibrations when used.

Trusses

The problem for the fire service from these highly engineered items has already been described in chapter 2. If any part of the truss fails, then the entire truss will fail, most of the time very suddenly. When and if you have to shore a truss, always shore the top chord. If you shore the bottom chord and one of the shore's elements fails, you may still have to contend with the failure of the remaining part of the truss. By shoring the top chord, you will support the weight above and hold that weight in position, safely stabilizing it.

Types of void access

If there are numerous voids with victims trapped, most likely some type of shoring lumber will be needed. Generally, cribbing size lumber is adequate; roughly 24 inches long usually works well. In some collapses there may be much larger voids, and in these situations, longer lumber sizes may be needed. Determine the access to those specific voids, and assess the feasibility of placing larger sized lumber in the void.

Bearing wall stability

The most important structural elements in any unframed building are its bearing walls. Most of the structure's weight and any loads in the structure are supported by these walls. In a collapse situation, failure of any part of any of these walls can cause extensive damage and further collapse. Check for the integrity of the wall; look for any bulges, bellies, cracks, leaning, or any type of possible deflection or abnormal deformation of the wall. Are any sections of the wall damaged or missing? If a wall is damaged, it may no longer have its full load-bearing capacity, making that area a weak point in the structure. If a section of wall is missing, additional stresses are being applied to the floor beams above and to the remaining sections adjoining the wall. This is a very dangerous situation. If structural stability is compromised, or if there is any doubt concerning the wall's structural integrity, the shoring officer must decide where and how much to shore. If you find any of these problems mentioned here, the foundation should also be checked. If any of these conditions do occur, then shoring may have to be considered.

Rules of thumb

These are a few rules of thumb that can be easily applied at the rescue site if necessary. They will work on most occasions; however, bear in mind that each structural collapse situation is different, and any unique circumstances must be taken in to account.

There are four basic guidelines for using existing floors in a damaged structure for the support of unstable walls, debris, or other floors:

1. It takes one undamaged wood-framed floor to support one damaged wood-framed floor.
2. It takes two undamaged steel-framed floors to support one damaged steel-framed floor.
3. It takes three undamaged reinforced concrete floors to support one damaged concrete floor.
4. The thickness of any debris on the damaged floors must also be taken into account when calculating the amount and type of shoring your team will need.

If your team responds to a parking garage collapse (which occurs a couple of times a year around the United States), shoring operations should be started from the ground up in almost every situation.

Lumber for shoring operations

It is critical to collapse rescue response to have quick access to lumber for shoring or cribbing operations. One way of accomplishing this is by contacting the local lumberyard and prearranging for quick delivery of specified lengths, sizes, and type of lumber that your team may need. Another option is to contact the local department of public works or a large building contractor who has shoring materials on hand. By preplanning, your team may be able to have prompt access to lumber for shoring operations. However, the only way your team can be guaranteed that the needed materials will be on-site is by bringing them there yourself. There are too many variables involved when you depend on someone else. For example, what if the collapse operation occurs after working hours? What if it is a busy day, and the lumberyard has no trucks available to deliver materials? These problems could cause unnecessary delays that can lead to tragic results.

Lumberyards stock most types of lumber that are appropriate for shoring. The following sections describe some of the more common types that are used in the construction industry and should be readily available.

Hardwoods and softwoods

There are two major categories of wood: hardwoods and softwoods. These names really tell us more about the type of tree the lumber comes from than the wood itself. For example, balsa wood, the easily cut and lightweight wood we all used as kids, comes from a hardwood tree. These names do not necessarily mean that hardwoods are hard or softwoods are soft.

Hardwoods come from broad leaf trees that lose their leaves during the winter months. The wood is generally heavy and close grained; oak and maple are two examples of common hardwoods. They are generally expensive and very heavy and are not well suited for our needs as a rescue team.

Softwoods come from trees with needle- or scale-like leaves that stay on the tree all year (Christmas trees). The most popular species of softwoods are

Douglas fir, western hemlock, white fir, and spruce. Douglas fir is one of the strongest woods available, and it stores well. It resists warping, cupping, and twisting, and it is inexpensive and readily available at lumberyards throughout the United States. For these reasons, Douglas fir is the first choice of lumber for the collapse rescue team.

Each piece of lumber delivered by a reputable mill should have a grade stamp. This stamp certifies that the piece meets quality control standards set by the lumber grading associations. The grades we will be looking for are No. 1, No. 2, stud grade, and construction grade. Utility grade should not be used, because it may not be strong enough in some situations.

Douglas fir and yellow fir. This is a strong, medium-density, medium-to-course textured softwood. It is widely used for plywood and dimensional lumber and timbers in a variety of building construction.

Oak. This is a tough, hard, high-density, coarse-textured hardwood found in temperate climates. Oak is used for both structural and decorative applications. Framing timbers, flooring, molding, and plywood are some of its many uses. The two most common types are the white and red oak varieties.

Use of existing lumber

In most collapse situations, the tendency will be to grab any available material and go to work. If your team does not carry lumber with them, they will use whatever they can get their hands on. This often means the material that was involved in the construction of the collapsed structure. Evaluation of any material must be made before the rescue team commits to utilizing it for rescue operations. There are several factors that should be checked before you use that material for any rescue shoring, including age, type, condition, and how much stress the material has been subjected to. The age of the building will give you an idea of the condition of the lumber. In newly constructed buildings, the lumber should be in good shape; much older structures may have weathered material that can be fatigued and difficult to work with. The type and size of the lumber are issues to consider as well. Smaller lumber such as 2 × 4s cannot be used as main bearing members without nailing them together. Cedar and redwood decks cannot be torn up and used as structural bearing members because they are too soft.

The single most important factor in the decision whether to use the lumber is the condition of the wood. It must be thoroughly examined. If it is too dry or brittle, it will split and crack easily and will not stand up under any type of stress. If it shows signs of rot or is extremely wet, it will also be unusable. Finally, examine the lumber for any twists, bows, cracks, or splitting. If any of these conditions is present, the lumber should not be used for rescue operations.

Nail usage

Nails are classified according to their use and form. They are designated by the term *penny*, which for our purposes is abbreviated by the letter “d.” The term *penny* came from the marketplaces of the 1400s. This was the price of 100 of a particular size of nail. Nowadays penny refers to the length of the nail regardless of the size of the wire gauge. Nails come in various sizes, from 2d to 60d, or from 1 to 6 inches in length. The most common type of nails we will encounter are fabricated from steel wire. Nails should be at least three times as long as the thickness of the lumber they are holding together. Two-thirds of the length of the nail should pass into the second piece of lumber. The nails can be driven at a slight angle toward each other to keep them from pulling apart. There are several types of nails in use today: finish, box, common, galvanized, threaded, ring-shanked, duplex, and resin-coated, to name a few. The one used the most for rescue situations is the common nail. In training scenarios, it is a good idea to use the duplex head nails. Drive the nail to the first head, and for ease of removal the second head will stand up out of the wood and can easily be pulled by crowbars, nail pullers, or steel-handled hammers. By using these nails, the lumber will not be severely damaged as it is taken apart and can be reused several times, making the training economically feasible. The nail sizes we will normally be using are 16d for nailing 2 × 4s and 4 × 4s together and 8d for plywood gusset plates or toenailing wedges. Both of these nails will usually be the common type, unless an engineer specifies another type. Pneumatic nails for use in pneumatic-powered nailers come in strips or coils, depending on the type of nailer. Most of these nails come with a resin coating for better holding power. One type that your rescue team should insist upon is full-head nails. Some of the nailers shoot nails with half or three-quarters of the nail head, but in rescue situations, the nails should have their full heads

for better holding power. Your team can decide which type of nails they wish to use.

Nail patterns. In order to get the proper holding power with common nails, certain nailing patterns are normally followed. The most common application for these patterns is the fastening of plywood gusset plates and 2 × 4 or 2 × 6 cleats. In the construction of raker shores, the nail patterns on the cleats and gussets are very important because proper holding power depends on the “d” number of the nails. For ¾-inch plywood gusset plates, 8d nails are generally sufficient. In the 2 × 4 or 2 × 6 cleats used on raker shores, 16d nails should be used. When using a 2-ft cleat made of 2 × 4 lumber, you will need 16d nails. They can be staggered or nailed in a “five nail pattern” fashion, which will give you 14 nails. When using a 2 × 4 cleat that is 30 inches long, for raker shore angles over 45°, you will need 20 type 16d nails to have the proper holding power to prevent the rake from sliding up the wall plate.

When using a 2-ft-long 2 × 6 for a cleat on a 4 × 6 or 6 × 6 raker shore, the nail total will be 20 type 16d nails. They can be nailed in a staggered pattern of three rows. For the same width cleat that is 30 inches long, the number of nails will be 29 type 16d, and they can be nailed using the same pattern.

Wedges

The proper use of wedges is very important for a successful collapse rescue operation. Wedges are normally used in pairs. When properly joined or “married” together, they are excellent tools for filling gaps and transferring collapse loads. They are easily adjustable and can be tightened just enough to transfer loads without lifting them. Moving unstable loads can have serious consequences in a collapse operation. It is imperative that all your personnel have been properly trained in the use of wedges. This may sound trivial, but it is extremely important. The use of wedges is extensive in all types of shoring operations—interior and exterior, as well as any type of void shoring and stabilization. For a wedge to fit properly and snugly, its length should be only five to six times as long as its thickness. Wedges constructed with too sharp an angle will not hold properly and can easily slip out. The width of the wedges should be the same thickness as that of the other materials you are working with. This will make for a much smoother operation. Wedges that are too large will hinder the installation of any bracing, and

smaller wedges may make the shore slightly unstable. Some of the more popular sizes of wedges your team can construct and use are (all in inches):

- 2 high × 3½ wide × 12 long
- 1½ high × 3½ wide × 9 long
- 1½ high × 3½ wide × 12 long
- 3½ high × 3½ wide × 18 long
- 3½ high × 3½ wide × 24 long
- 3½ high × 5½ wide × 18 long

The wedges can be premade and carried on your apparatus, or they can be cut in the field. Generally, it is much better if you have a precut cache of wedges on hand. It will take time to cut the wedges to size; however, it can be done with a little bit of effort. The lumber can be cut with a small chain saw with a sharp blade. If you want to cut a 2 × 4-inch or 4 × 4-inch wedge in one pass, use a 10¼-inch circular saw. If you use a smaller diameter circular saw, you will have to make two passes, and your cuts may not line up, making your wedges almost useless because they will not fit together properly and will not tighten up sufficiently to be effective.

Lumber uses

The following is a list of lumber sizes that should be carried on your collapse apparatus, if at all possible, and some of the more common uses for each.

- 2 × 4s—This size lumber can be used in box cribbing as diagonal bracing for interior raker shores, cross bracing for laced posts, interior and exterior raker shores, various size cleats, filler blocks, and diagonal bracing for vertical shores.
- 2 × 6s—Can be used for diagonal wall braces, diagonal braces for vertical shores, interior and exterior raker shores, box cribbing, cleats for raker shores, cross bracing and horizontal bracing for raker shoring, and horizontal struts for split-sole rakers and flying raker shores.
- 2 × 8s—Although not commonly used, they are excellent for sleepers or mud sills when shoring is being erected on soft ground. They can also be used as diagonal wall braces.

- 4×4 s—The most common size of shoring lumber your team will need. Box cribbing, T shores, window shores, door shores, laced posts, vertical shores, horizontal shores, and interior and exterior raker shores can all be constructed with 4×4 s.
- 4×6 s—Generally used in larger buildings or where substantial holding power is necessary. They can be used as door and window shores if heavier loads are anticipated or as interior or exterior raker shores if necessary.
- 6×6 s—Normally used in heavier constructed buildings where the loads will be much greater, such as an all concrete or concrete and steel structures. They are good for use as box cribbing, raker shores, vertical shores, laced post shores, and return blocking for a series of raker shores.
- $\frac{3}{4}$ -inch plywood—This plywood can be used for numerous items such as gusset plates, cribbing spacers, and wall plating for raker shores; in trench rescue; and as work platforms and sawhorses.

Length-to-diameter ratio

One of the most critical factors when doing a shoring size-up is how much weight needs to be supported. Determining the length-to-diameter ratio of shoring elements is very important. The main supporting elements in shoring are posts or struts. These may need additional support or tensioning, which will be done with lateral bracing.

Euler's formula for columns comes into play with all our shoring systems. Swiss mathematician Leonhard Euler (1707–1783) proved that a thin strut or column submitted to an axial compressive load will not remain straight. It will bend out suddenly or buckle at a specific value of the compressive load. This is called its critical value. Because any element that comes under compression acts as a column, whether vertical, diagonal, or horizontal, all shoring systems will be subject to this condition. By limiting the length of the posts or struts, we can keep the strength at the most efficient levels. That is one of the reasons why we brace shoring systems. The longer and thinner the element is, the less it will support. By center or

lateral bracing these elements, we can achieve the optimum strength of the lumber. In most cases (of course there are always exceptions), keep the ratio of the posts at a maximum of 50 to 1. For example, a 4×4 actually measures 3.5 inches. Multiplied by 50, this gives 175 inches, which for our purposes roughly equals 14 feet. This would be the maximum to shore up something lightweight. In the typical buildings in the United States, the ratio should be closer to 25 to 1. This helps us keep the lumber's shoring capabilities near its maximum strength. By multiplying the same 4×4 by 25, the length is 87.5 inches. For our purposes, use the length of 8 feet as a guideline for lateral bracing of shoring systems. Of course, since each collapse situation is unique, your main consideration in determining the lift-to-drag (LD) ratio of your shores will be the amount of weight the shore will be supporting. As a general rule, again, no more than 50 to 1 and ideally roughly 25 to 1 will be the most efficient use of the shoring materials' strength. Generally, we will not be dealing with anything larger than 16 feet. Any longer would be a special-order item not readily available, not to mention expensive. Only when dealing with larger timbers such as 8×8 or 12×12 will you normally encounter longer beams.

Initial Safety Shoring

Before rescue shoring of any kind is erected, the need for initial safety shoring must be considered. The decision to use of any type of safety shoring must be included in the initial size-up conducted by the rescue team. Before any extensive rescue shoring operations can be undertaken, the safety of the operating forces must be considered as one of the team's paramount concerns. Some of the factors that must be taken into account in your initial shoring size-up are the extent of the damage, the stability of the remaining structure, possibility of victim entrapment, reasons for the collapse, and the extent of the shoring operation.

Initial safety shoring in void operations

As the debris is removed from the void and after the area to be cribbed has been determined, an initial or safety shore should be installed. By placing a screw-type or pneumatic-type shore with a locking collar,

you will give the rescue team a degree of safety while the crib is being erected. When using these shores, the main function is to support the existing structural elements, generally beams or joists. Directly supporting these elements is the most effective method; however, this is not always possible. If it is not possible, then solid blocking can be used with these shores to help transfer the load stresses to adjoining structural elements. Place the safety shore near the area to be cribbed and tighten up enough to firmly support the load. Do not overtighten and lift the material, as this could cause debris to shift and possibly cause a secondary collapse. Anchor the shore in place to guard against any accidental contact that may knock the shore loose. This shore must be monitored continually while the crib is being erected to make sure the shore is still supporting the load safely.

If you cannot use an adjustable pneumatic or mechanical shore, then bring into the void with you one or two lengths of 4×4 lumber. They can quickly be placed in operation if the need arises. A length of 4×4 -inch material with a 4×4 -inch cap on each end makes for a nice substantial safety shore. A handle attached to the center of the shore makes it easier to carry and maneuver into position. The overall length of the shore should be between 20 and 24 inches high. Bring a set of wedges into the void with you, because this will help make the shore somewhat adjustable. The wedges can be used to shim the shore plumb, or a married set of wedges underneath the shore will add several inches of adjustable height to the shore, making it that much more adaptable.

T shore

Before a thorough size-up can be attempted, often there will have to be some type of initial safety shoring erected in place. Before any extensive shoring can be installed, due to the suspected instability of the structure, the same type of initial safety shoring must be constructed. This is where the T shore is invaluable (figs. 5-1 and 5-2). It can be erected very quickly, and it is easily movable and can be adjusted to fit with little effort. It takes up very little room and can be put together outside the danger area. It can then be quickly moved into position, erected, and secured.

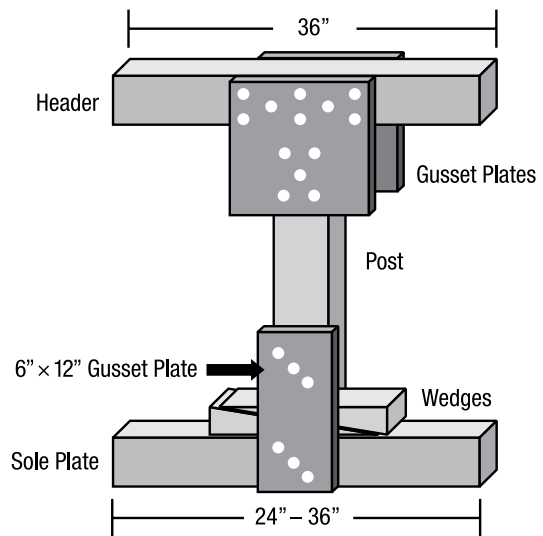


Fig. 5-1. T shore



Fig. 5-2. A baby T shore helping to support a collapsed roof section in order to allow void searching to be performed

As figure 5-1 illustrates, the T shore consists of a header to collect the load, a soleplate to distribute the load, wedges to adjust the post tightness, a post

to absorb the load from the header and transfer it to the soleplate, two gusset plates to lock the header and post together and stop any shifting from occurring, and a 2 × 4 cleat anchored at the base to keep the wedges in position and lock the post into the soleplate. The T shore typically is constructed of 4 × 4 lumber. Use Douglas fir if possible. The header should be no more than 36 inches long; any longer, and the shore may become unbalanced. The soleplate can be the same size or as small as 24 inches, depending on the type of structure. In a concrete or steel building, use the 24-inch soleplate; in wood frame, use the 36-inch soleplate.

For wood frame and brick-and-joist buildings, the T shore can be constructed of 4 × 4s with either 2 × 4 or 4 × 4 wedges. The materials you will need to erect one shore will be two 12 × 12, ¾-inch plywood gusset plates; one 24-inch, 2 × 4 cleat; one 36-inch, 4 × 4 header; one soleplate at least 2 feet long, up to 3 feet long; and one pair of 4 × 4 wedges, 18 inches long, or a set of 2 × 4 wedges, at least 12 inches long.

The safety shore will be built before the rescue team erects the more permanent and stronger vertical shoring. It is advisable to erect at least two of these initial shores before any other shoring work is attempted in the danger area. Two shores are normally enough to protect your shoring team while they erect the vertical shores. The vertical shores average 10 to 12 feet in length; any longer, and they may become much tougher to handle and require too extensive an area to clear out.

Double T shore

The double T shore is used when more stability or support is called for (figs. 5-3 through 5-7). It is still considered a temporary safety shore, not a permanent one. As with the single T shore, it is prefabricated and walked into position. The maximum header length of a double T shore is 36 inches, and it is constructed of 4 × 4s. The two top gusset plates are 12 × 24 inches, and the center gusset plate is 12 × 24 inches.

The strength of this shore when properly loaded is generally more than twice that of the single T shore. This shore can be constructed in one of two ways: with the posts spaced 18 or 24 inches apart, outside to outside. Determine on the scene which spacing you want to use. Generally the amount of space you have to maneuver the shore would determine the post

spacing. In a tighter area, use the 18-inch spacing; for a wider area, use the 24-inch spacing.

When the shore is installed less than 6 feet high, you only need the top two gusset plates. The middle gusset is there to keep the posts from separating when they are longer than 6 feet.

Two sets of wedges are installed at the bottom of both shore sizes. Make sure that both sets of wedges are tightened up evenly.

When the shore has the posts spaced 24 inches apart from outside to outside, there is a 6-inch overhang of the header over the ends of both posts. When you use the 18-inch spacing, the overhang on both ends will be 9 inches instead of 6 inches. In this case, you still would use the 12 × 24-inch gusset plates; they would just overhang the posts 3 inches on each side.

Figure 5-3 illustrates a double T shore consisting of the header and soleplate, both 36 inches long. Two posts each sit on a separate set of 2 × 4 wedges. The gusset plates are always two at the top, one on each side, and one center gusset plate if the shore is 6 feet or taller. At the base are two 2 × 4s used to hold the posts and wedges to the soleplate. This shore is generally erected with 4 × 4s.

Figure 5-4A illustrates a prefabricated double T shore with the posts at 24 inches outside to outside. Here the posts are flush with the ends of the gusset plates, and the header overhangs the posts 6 inches. Figure 5-4B shows the shore prefabricated with a 36-inch header, two gusset plates and the two posts 18 inches outside to outside. Notice the 3-inch overhang on each side of the gusset plates; this is fine. The overhang for the header is 9 inches on each side.

Figure 5-5 shows two finished double Ts on top of the wedges and soleplate. On the left are the 24-inch-wide posts and the center gusset plate is attached. The center gusset plate is flush with the ends of the posts just as the top gusset plates are. On the right is the completed double T with the posts set at 18 inches. Notice that the center gusset plate at 12 × 24 inches also overhangs the outsides of the posts, 3 inches on each side that overhang the top gussets. This is fine, but just make sure that the gussets are nailed properly to the posts. This gusset is only in place to stop the posts from spreading apart during transportation and installation.

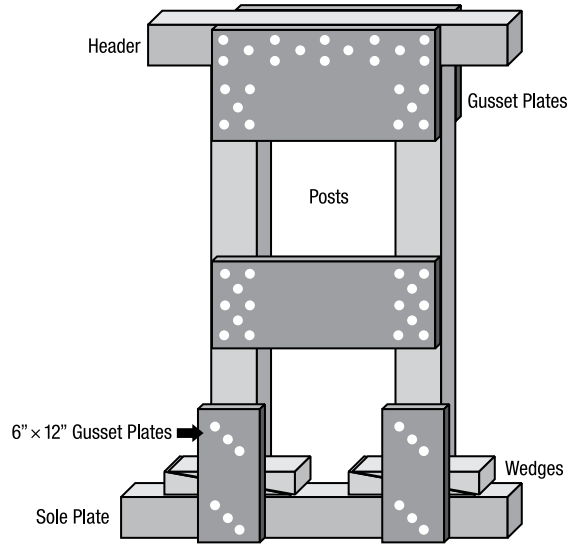


Fig. 5-3. Double T shore

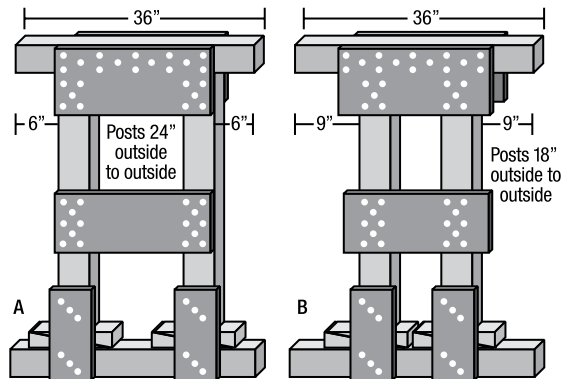


Fig. 5-4. Prefabricated double T shores

Figure 5-6 shows two double T shores holding up a collapsed section of bar joist and metal decked roof. In this case, the double Ts were partially constructed, and only the posts were anchored to the header. The partially constructed shore was then placed in the web of the truss and erected underneath the top chord. The gusset plates were then anchored to the shores while they were in place. This gives the T shore better stability while holding up the top chord of the truss and keeping the shore centered under the truss.

Figure 5-7 shows two double T shores holding up the overhang of a collapsed roof. Both of the shores are less than 6 feet high and thus do not have the center gusset plate anchored to them.



Fig. 5-5. Two finished double Ts on top of the wedges and soleplate



Fig. 5-6. Two double T shores holding up a collapsed section of bar joist and metal decked roof



Fig. 5-7. Two double T shores holding up the overhang of a collapsed roof

Interior Rescue Shoring

This section describes the most common types of rescue shoring for collapses of wood frame, reinforced, and URM structures. The main objective of interior shoring is to resupport, replace, or reinforce damaged structural elements from the inside of the building. It is used to support sagging floors or roofs and stabilize walls, bearing members, windows, doors, and racked or unstable openings.

Box cribbing

One of the simplest types of shoring is box cribbing. It is quick and easy to install. Its main advantages are ease of installation and strength. The two main drawbacks are that it can crush up to 20% of its height and is not very laterally stable. As simple as it is to erect, it also takes quite a bit of lumber to assemble a crib. Dozens of pieces typically make up an average crib. When installing cribbing, make sure there is a safety shore in place, because the crib holds nothing until it is tightened up and pressurized. You must also make sure that the crib is loaded evenly, or it will become unbalanced. Most of the collapses that we respond to are in wood frame structures, and the use of 4 × 4 lumber for cribbing is more than enough for that. Anywhere from a 2× to a 4× crib would generally be sufficient. In larger masonry, concrete, or steel struc-

tures, 4 × 4s may be fine in certain areas. However, the team should be thinking about using 6 × 6s if necessary.

Another advantage of cribbing is that it can be used in a confined area. In small, open areas you can easily slide the crib pieces in and set them up. The cribs can be assembled at an angle; they do not have to be square. Bear in mind that when a crib is installed at an angle, its stability changes. Instead of the typical ratio of three times the height to the width, called the 3:1 ratio, you can wind up with only a 1½:1 safe ratio.

Rule of thumb for cribbing. Keep the use of cribbing to a specific maximum heights. Extensive testing has shown that cribbing erected too high is unstable. *Do not* erect 4 × 4 cribbing higher than 4 feet or 6 × 6 cribbing higher than 6 feet. For anything above those heights, use other types of shores instead (see figs. 5-8 through 5-30).

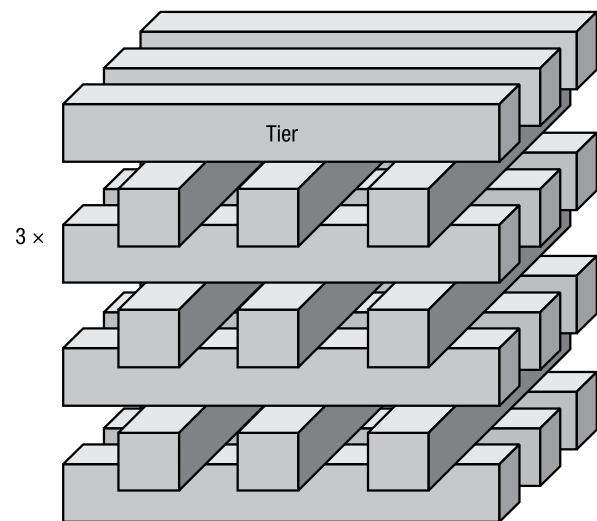


Fig. 5-8. Identify the different parts of cribbing. Each layer is known as a tier; this figure has seven layers or tiers. The crib is identified by the number of pieces per tier; this is a 3× (by) crib with three pieces per layer. Make sure you overlap the ends of the cribbing. Overlap the cribbing on each layer. The overhang should be the same as the thickness of the cribbing material, 4 inches for 4 × 4s and 6 inches for 6 × 6s. The maximum height that cribbing should be stacked is three times the height to the width. As the cribbing grows to be more than 3 ft high, switch to other shoring options. There is more room to install the other types of shores, and they will use less material.

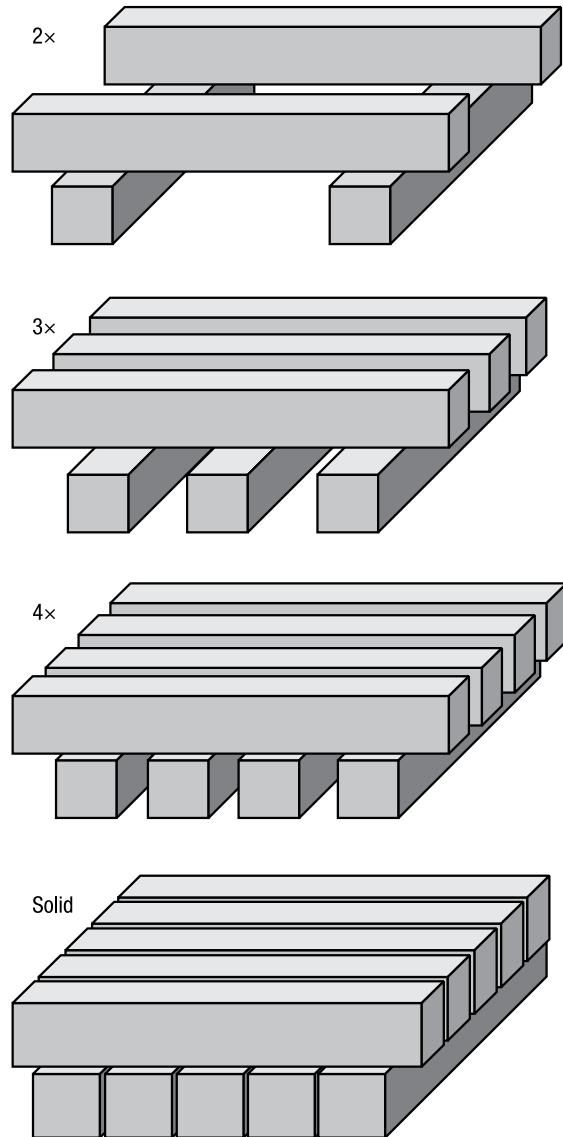


Fig. 5–9. Cribbing is named for the number of pieces of lumber on each tier or layer. The 2× crib has two pieces of lumber per tier, the 3× crib has three pieces per tier, and the 4× crib has four pieces per tier. The solid crib has full capacity and no spacing. Generally a solid crib is not necessary unless you want to spread the load out on soil or soft ground.

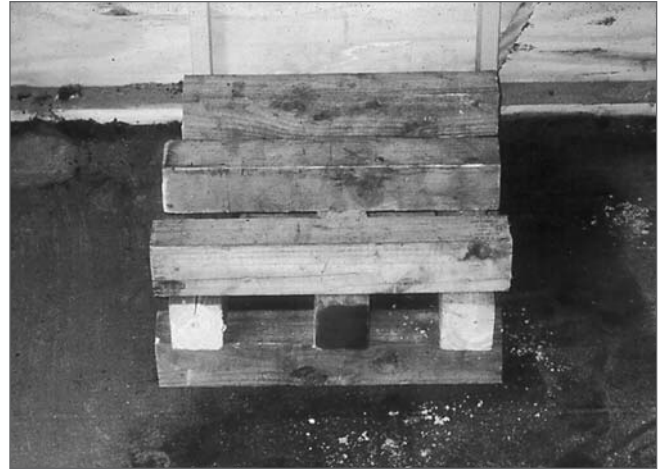


Fig. 5–10. In this 3×, three tier, 4 × 4 box crib, the cribbing is 24 inches long. This is known as a cross tie crib, because each layer is at a right angle to the next.

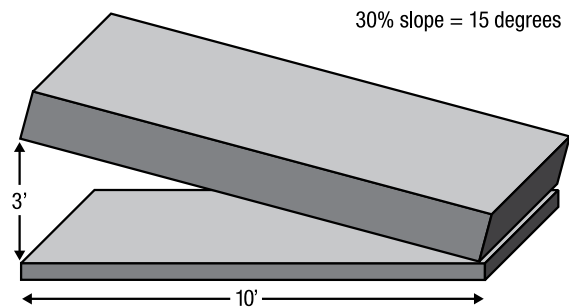


Fig. 5–11. The sloped-floor shore will take precedence over box cribbing when the slope of the floor is over 30% or the opening in question is greater than 3 ft high. The easiest way to determine if the slope of the floor above is more than 30% or 15° is to measure a triangle. If the floor section is 10 ft long and goes from 0 to 3 ft high, then the slope is 30%. For slopes higher than 30%, switch to a sloped-floor shore, because cribbing would be unstable and probably would be dislodged under an impact load.

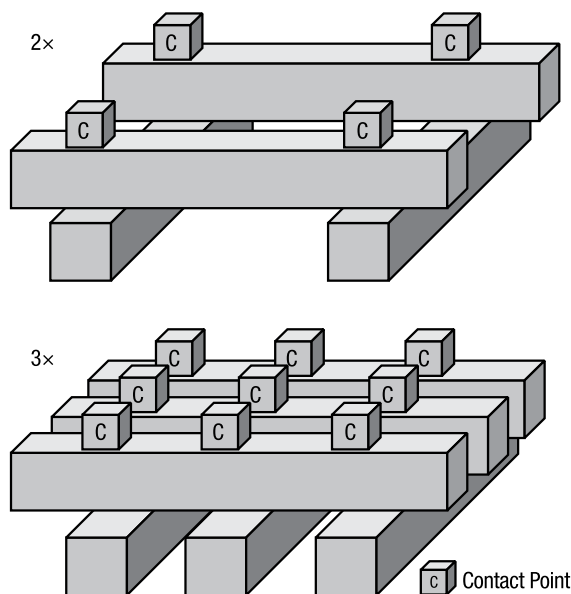


Fig. 5-12. On a 4 × 4 Douglas fir crib, each contact point is good for 6,000 lbs of compressive strength, with roughly a 2 to 1 safety factor. The contact point is where the two pieces intersect each other. On the left are four contact points, roughly 24,000 lbs of rated support. On the right are nine contact points, worth 56,000 lbs of support.

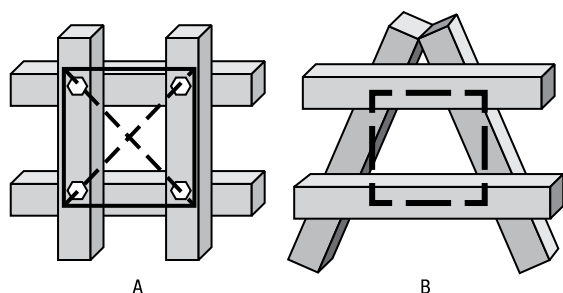


Fig. 5-13. (A) It is important to keep the balance of the load over the center of the crib. Be aware of the limitations of the crib balance. Every time a crib is used, make sure that there is full bearing on all the contact points. A crib will not fully function if all the contact points are not under compression. Each crib must have full compression of all its contact points in order to be properly loaded. (B) Typically, three times the height to the width is the rule of thumb. However, with angled cribs, the ratio can be as low as 1½ to 1. Keep this in mind when assembling your odd-shaped cribs. You can see here that the imaginary square is much smaller than the back of the crib, making this crib not as efficient as it should be.

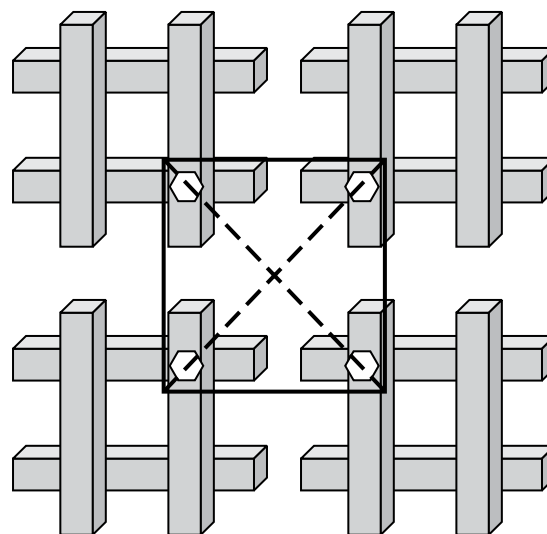


Fig. 5-14. Cribbing set up and loaded like this is unstable and only good for 6,000 lbs per crib, which is not very efficient. Although it looks like it is transferring the load out, it is in fact not doing that and is very unstable. This instability is due to the uneven loading of all the cribs.

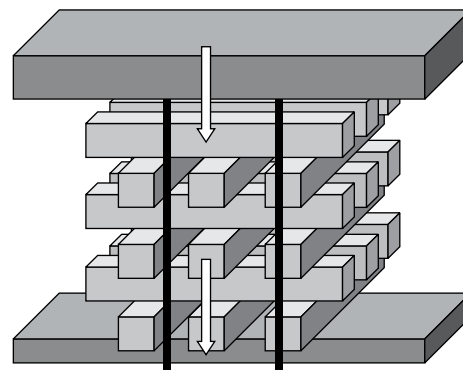


Fig. 5-15. It is very important that the crib be balanced and that the load be in the center third of that crib. This will afford you the most efficient use of the crib's strength. Keep this in mind at all times. If the load is not centered, the crib will be unbalanced.

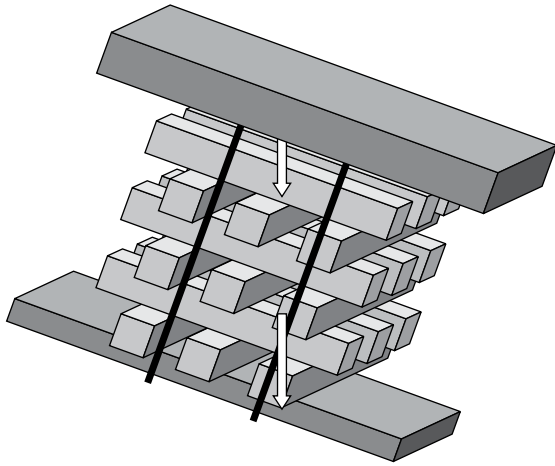


Fig. 5-16. This is the maximum angle for installing box cribbing, 30%. If the load of floor above is at a greater angle, the crib will not be able to fully distribute the load through itself.

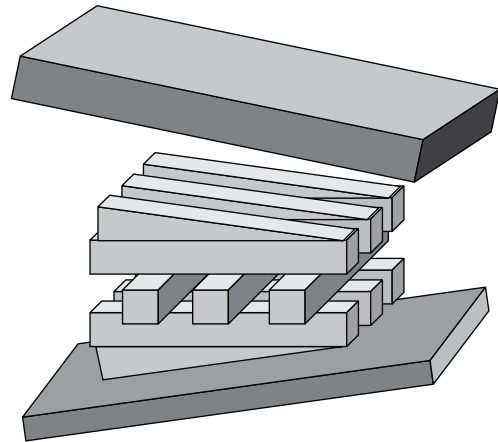


Fig. 5-18. When erecting cribbing on top of uneven surfaces, use wedges to compensate for the angles. Try to gradually slope the crib to the proper angle.

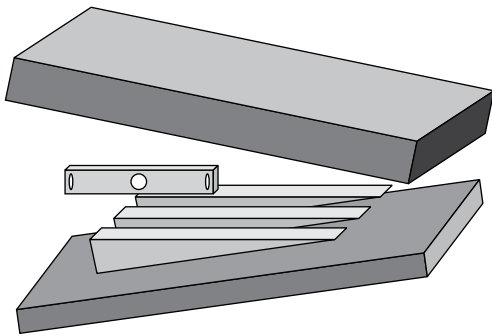


Fig. 5-17. When erecting cribbing on a unlevel or uneven surface, first try to place a set of wedges or blocks in position to start your crib level. It is much easier to erect cribbing when it is nearly level.

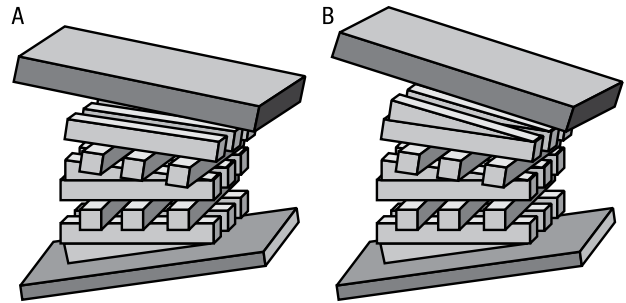


Fig. 5-19. (A) Here the slope of the crib is gradually being changed to match that of the upper floor to be supported. Placing wedges every few layers is better than putting all of them at the top. (B) Here only one set of wedges is needed at the top to tighten up the crib. The closer the slope is to parallel, the easier the crib is to install.

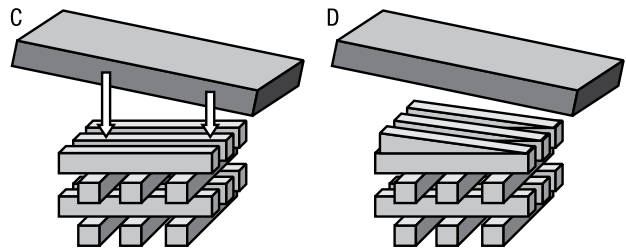


Fig. 5-20. (C) When assembling cribbing on a level surface to support an angled floor above, begin by erecting the cribbing level. (D) When getting close to the angled floor above, start placing wedges in position to match the floor angle.

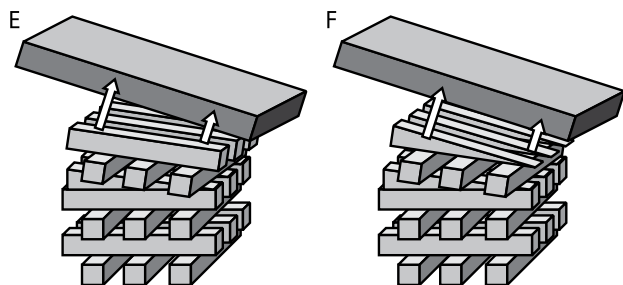


Fig. 5-21. (E) When installing the cribbing at an angle, it is good practice to try to get the angle as close as possible to parallel to the floor in question at least two layers of cribbing before the floor. (F) Wedging the crib at an angle until it is parallel to the upper floor will make it far easier to install the last two layers of cribbing.

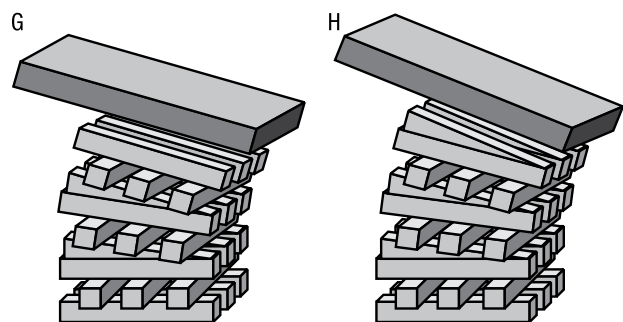


Fig. 5-22. (G) To maintain the proper angles, use wedges on each successive layer: one set of wedges and one set of cribbing. When the slope is parallel to the floor, put the rest of the cribbing together. Try to gently angle the cribbing to the upper floor, but do not drastically angle the crib, which will just make it unstable. (H) Here is the crib completed. Notice the close fit at the top of the crib; all that is needed is a thin set of wedges to tighten up the crib. Gradually angle the crib to make installation easier and more efficient.

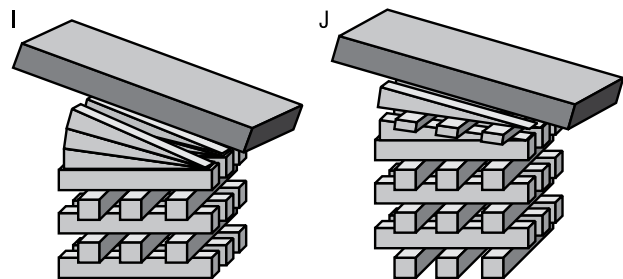


Fig. 5-23. (I) Do not place more than two wedges on top of each other or the cribbing will fail under pressure. Any force on the crib will cause the middle wedge to come flying out. (J) When an angle needs to be wedged, think of various options. Instead of three wedges on top of each other, you can use two wedges and place a board in between the wedges. It can be a 2 × 4, plywood, or whatever is necessary. The cribbing must be stable to be safe.



Fig. 5-24. An angled box crib under a sloped floor. Notice the different levels of wedges, 2 × 4s, and plywood and how they gradually have angled the cribbing to the proper point.



Fig. 5-25. Here is a crib approximately 36 inches high. Notice how it is sloped before getting to the leaning floor section. Wedges were placed on the soil to get the crib level; a sheet of plywood was also installed on top to help evenly distribute the load to the ground. The crib was sloped to the floor's angle two levels below, making the final installation of the last two layers of the crib much easier to assemble and fit in.

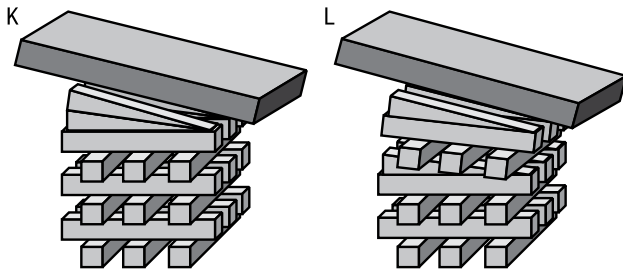


Fig. 5–26. (K) It is often possible to assemble the crib level and then place one or two wedges in position to secure the crib and pressurize it properly. Make sure that you securely anchor these wedges and nail them in place so they will not move under pressure. (L) Gradual angling a crib is far more effective and efficient than just adding wedges at the end. There are more secure nailing points, and the transfer of weight to the crib is more effective.



Fig. 5–27. This crib is gradually sloped until it fits perfectly. The wedges in the crib can be pressurized to tighten up the crib properly.



Fig. 5–28. This crib is angled up, and then wedges are used to tighten it up to the floor. The floor is sloped in two different directions, hence the different angled wedges.



Fig. 5–29. A 3× cross tie crib being used to support a cracked concrete column. The concrete is supported on both ends already, so the crib doesn't have to bear the full weight of the entire column. You need to roughly calculate how much of the weight of the concrete that needs to be supported.



Fig. 5–30. This crib is holding up the entire corner of a shifted second floor of a townhouse. The opposite side of the wall has been raker shored, stopping the wall section from sliding any further. The crib is strictly holding up the weight of the corner.

Sloped-floor shore

Sloped-floor shoring is complicated to erect. Often it needs to be installed in a tight area. The main purpose of this shore is to stabilize the floor above and cover a substantial area in the process. Sloped-floor shores are extremely strong when erected properly. They must be anchored properly or they can easily slide under pressure and thus be useless.

Collapse Operations for First Responders

Sloped-floor shores are used for large sections of flooring that may be leaning, propped up, or otherwise lying on a drastic angle to the ground, or if the opening is several feet in height (see figs. 5-31 through 5-38). If the opening is greater than 3 ft high, other types of shoring, such as sloped-floor shoring, may be more efficient than box cribbing. There are times when searching inside a collapsed structure that drastically sloped floors or even walls may be encountered. In many cases where these are heavily damaged and deemed unsafe to enter without shoring, some stabilization may have to be accomplished first.

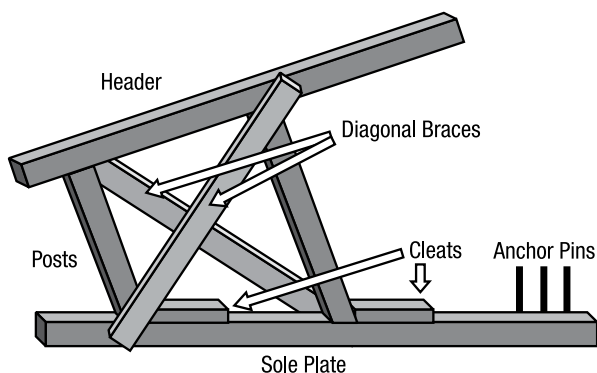


Fig. 5-31. The perpendicular to the load sloped-floor shore has a solid base. This is the one we would use when the slab or floor above cannot shift or slide. Like raker shores, these shores must be erected in pairs. Although very strong as a unit, as a single entity, they would be too laterally unstable. The shore consists of two posts, a header, a soleplate, cleats, and diagonal braces.



Fig. 5-32. Two posts and bases properly secured and anchored with minimum size cleats. If your post angle is as steep as the one shown, you may want to increase your cleat size to 18 inches instead of the minimum 12-inch cleats. The steeper the post angle, the greater the lateral force against the cleats, forcing a larger cleat to accommodate more nails.

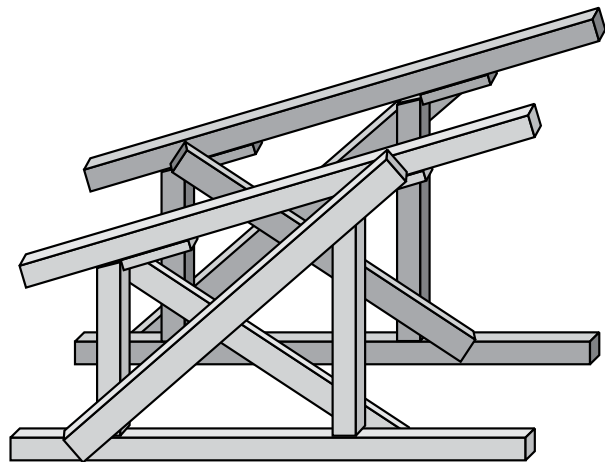


Fig. 5-33. The friction method shown here is used when the slab or floor above is not anchored down and may slide or shift. With the posts in this direction, the shore is more stable. The rule of thumb in this situation is that when the slab or floor is buried in debris and cannot shift or move, use the perpendicular method. When the slab or floor may shift or slide, you would set the posts as shown.



Fig. 5-34. Here is a friction sloped-floor shore finished and properly braced off. Notice the steep angle of the bracing. This is normal. You need to make sure that the braces always contact the header, soleplate, and post on both sides of each leg of the shore.



Fig. 5–35. Here a shore is centered under this unstable slab. Determine before you erect the shores where you will be placing them and how they will be oriented. This is very important, because once installed, they will not be able to be moved or shifted. The shores need to be lined up at the proper distance, and the posts must align with each other in order to brace them properly. Whenever installing sloped-floor shores, you must always install more than one. One shore alone is too unstable. As the two shores are installed, they must always be horizontally and diagonally braced.

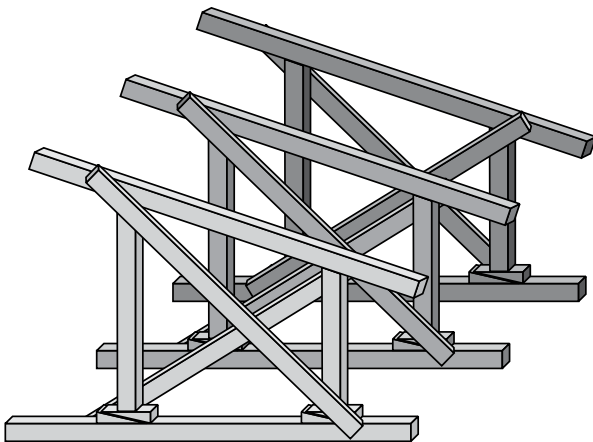


Fig. 5–36. Whenever erecting sections of the sloped-floor shore, each section needs to be X-braced to itself. Notice the three sections here each with a diagonal brace system. Make sure that all the braces on the two outside shores are orientated the same way. Use 2×6 s for all bracing on sloped-floor shores. This size of lumber gives a greater nail pattern surface. You must X-brace each leg of the shore: one brace inside, one outside.

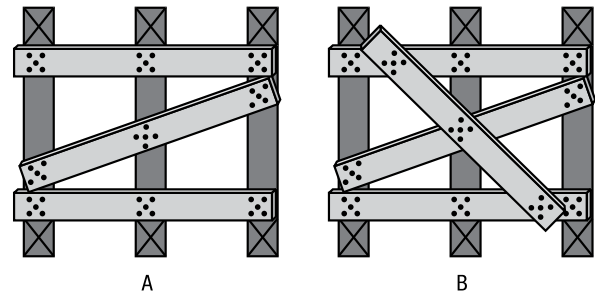


Fig. 5–37. (A) When tying the multishores together, follow the same rule as when tying two shores together. If all three shores are less than 8 ft apart, use two horizontals and one diagonal. Make sure you use 2×6 s. In the front posts, tie all three together with one or two 2×6 s, depending on the height. (B) When the shores are in a greater span than 8 ft, make sure that you install the other diagonal 2×6 brace. You need to have this X in place in order to stop any lateral movement in either direction from affecting the shores. Nail the two horizontals and the first diagonal 2×6 directly to the posts. The opposite leg of the X will be anchored on top of the other braces.



Fig. 5–38. Here a three-shore, two-post sloped-floor shore is in place under a loose slab that can possibly shift or slide. Make sure that all the braces run in the same direction. The back brace has the two horizontals as well as a diagonal. Even though this shore is not very large, there is a substantial possibility that the slab can shift. In this case, a diagonal should be installed to resist any lateral load against the shore.

There is another situation when the use of sloped-floor shores is indicated, when the slope of the floor has an angle greater than 15° or 30% . At this angle, the load applied against a crib often cannot be funneled through the center of the crib. This causes the crib to become unbalanced and possibly fail. Since the art of collapse shoring is neither exact nor precise, we will give several different types of shoring options that are

6

Rescue Personnel Uses and Training Criteria

Introduction

Two of the most important issues that must be addressed in structural collapse operations are the proper use of rescue personnel and the thorough and appropriate training of those rescuers. Coordinating the responding rescue personnel is one of the most difficult tasks the initial supervisors on the scene have to do. Establishing teams and positions before an incident occurs will greatly ease this organizational problem. It will also give the personnel assigned to these tasks time to plan their operational strategy, giving the incident commander one less job to be concerned about.

Training for the team should be an ongoing process. A continuing series of programs must be established and kept up to date on the newest training techniques and procedures for all facets of structural collapse operations. Live hands-on training is the most effective for this type of incident and should be a large part of the training curriculum. Although nothing can replace actual experience, training like you “fight” under the most realistic conditions possible will give your team the skills they need to be properly prepared for a real incident.

Technical rescue teams

Because any collapse is considered a technical rescue situation, your department needs to have qualified individuals responding to these incidents. Your department needs to meet the qualifications as specified in National Fire Protection Association (NFPA) 1670, and your rescue personnel need to meet the qualifications of NFPA 1006. These situations require specific rescue skills that the average firefighter does not have. When operating at a collapse, as at any incident, everyone involved needs to work together in a coordinated fashion. This is the safest and most practical way to accomplish the task.

Here are a few examples of the possible rescue team positions that your emergency personnel can be trained in and a sample of some of the subjects that the team should be learning about in order to be properly prepared for an actual response.



Void Search Team

The void search team has the most dangerous job in a structural collapse incident (fig. 6-1). Void searches must be conducted as safely as possible. These searches must be methodical operations accomplished by your department's best-trained and most experienced rescuers. A void search has to be completely coordinated with any other operation being conducted in and around the collapse structure. Anything happening around a void operation can easily affect what is going on in that void. Personnel must be kept off the top of the pile near these voids in order to control material falling down on the void search team.

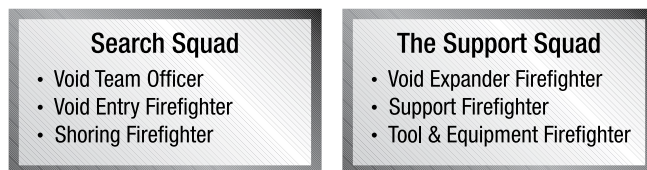


Fig. 6-1. A void search team is usually made up of six highly trained firefighters in two squads. The search squad consists of the void team officer, void entry firefighter, and shoring firefighter. The support squad consists of the void expander firefighter, the support firefighter, and the tool and equipment firefighter. The support squad relieves the search squad and supports its operations.

Void team officer

Control of void operations. The void team officer is in charge of the team and responsible for safe rescue exploration operations. This officer evaluates each step of the collapse void exploration and determines whether to continue the venture or adjust the operation based on a wide variety of on-scene factors. Safety dictates that, in general, the officer should take a position that allows close supervision of the void entry team, usually at the void access point, and yet be able to monitor the actions of the support team, not always the easiest thing to accomplish. The main position should be at the mouth of the void. The officer must be in constant communication with team members, particularly those operating in the void, and provide status reports to the operations chief, incident commander, or the void team officer's immediate supervisor.

Team assignments. The void team officer gives assignments to each member of the rescue team, based on the officer's knowledge of each member's experi-

ence, training, and expertise. Experience is probably the most important asset that should be considered. Trained team members who have collapse experience are invaluable. Their knowledge and experience will contribute substantially to the success of the operation.

Direction of tactics and procedures. The void team officer selects void entry routes and the tactics or procedures to be used in the void. These choices are made based on initial and continuing size-up, including type and size of the collapse, type of building construction, type and size of void, and last known victim location, if any. This officer constantly monitors the void's stability and safety and will be greatly assisted in this effort if the void entry team members have had previous collapse experience. This will possibly give them an edge in that they should be able to detect problems before they arise.

Coordination of victim assistance and removal. The void team officer coordinates the efforts of any medical personnel who may be assigned to treat the victim. This officer requests the medical assistance of a doctor, paramedic, or emergency medical technician (EMT) to determine the extent of injuries and administer immediate care to prevent crush syndrome injury prior to packaging and removal of the victim. When the victim is ready to be removed from the collapse debris, the void team officer will determine the route the medical personnel should take. Usually, this route is the same void opening that firefighters used to access the victim. However, as collapse operations are carried out simultaneously throughout the demolished structure, another void closer to the victim and the egress point of the building may be penetrated and cleared of debris, providing an alternate route. This additional route may be a much easier and safer way to remove the patient.

Crew rotation and relief. The officer must keep constantly alert for the first signs of fatigue in any team members. Using tired firefighters is dangerous and counterproductive. Firefighter relief is a judgment call by the officer based on the severity of the collapse, the amount of debris to be removed, the degree of the victim's entrapment, the duration of the operation, the distance between the victim and the access point, the necessity for multiple tools and duration of the cutting operation, and the physical condition of the firefighters performing the operation. These factors vary at every collapse situation, and the officer must take all of them

into account when evaluating the need for relief of the rescue personnel.

Void entry firefighter

Void entry. The void entry firefighter is usually the first rescuer to enter the collapse void area. This firefighter's main objective is to locate existing voids, penetrate them, and search them under the supervision of the team officer, who, with an accurate void size-up, can direct the firefighter to probable areas of victim entrapment. The void entry firefighter must be a knowledgeable and experienced firefighter who can operate in confined void spaces with minimal adverse effects. Not everyone is suited to this type of operation. This firefighter probably is subjected to the most danger during the void operation and must evaluate each action completely and methodically, for not only the firefighter's own personal safety but also the safety of victims and other operating personnel.

Debris removal. The void entry firefighter determines which material can safely be removed. Loose debris, bricks, wood pieces, small furnishings, and the like can be moved quickly and easily and without any danger of creating a secondary collapse. If the void is large enough, the material can be moved aside, out of the way of extrication, and still leave enough room for operations and victim removal. If the void is too small, the loose debris must be passed back and brought out of the void. Moving closer to the victim, the firefighter must handle each piece of debris carefully to ensure that no material will come loose and jeopardize the victim's safety.

Recommendations on what to cut. The void entry firefighter must determine if any of the remaining structural members have to be cut and removed for greater void penetration. Beams and other structural members can be cut only if there is a visible free end or if the structural element is loose, two sure signs that it is not supporting any other debris. If the structural member is tight within the debris, the firefighter must determine whether it is supporting anything or can be removed safely with the proper shoring and bracing. Main structural elements—beams, columns, arches, girders, and bearing walls—should not be disturbed unless absolutely necessary, and then only after having been properly supported. This phase of the operation is extremely dangerous and should be attempted only after having exhausted all other options for victim access.

Shoring firefighter

Assisting the void entry firefighter. The shoring firefighter is the second rescue member to enter the collapse void area. This firefighter's primary function is to assist the void entry firefighter whenever necessary—whether it is passing debris out of the hole, shoring structural members, or searching in tandem. The shoring firefighter must always stay in visual and voice contact with the void entry firefighter and in close physical proximity should any problems arise. This firefighter is the direct liaison from the void entry firefighter to the rescue officer.

Constant communication. The shoring firefighter functions as the additional eyes and ears of the void entry firefighter. This firefighter must maintain constant communication with the void team officer, monitoring the changes in the operation and relaying progress reports and any pertinent information. This leaves the void entry firefighter free to concentrate on extricating the victim.

Void safety. The shoring firefighter must make certain that the void is as safe and stable as possible. This firefighter must make sure that the egress for both of them (the shoring and void entry firefighters) remains open and that a secondary collapse does not occur. The shoring firefighter erects structural shoring members whenever necessary, with the assistance of the void entry firefighter or the void expander firefighter if needed. If the void is deep and debris removal extensive and time-consuming, the shoring firefighter must continually check that the existing shoring has not moved and wedges have not loosened. This firefighter must erect additional shoring as the void area expands.

Debris removal. An additional responsibility of the shoring firefighter is to remove collapse debris fed to him or her by the void entry firefighter. He or she may elect to slide this debris out of the way (if this option is available) or, preferably, remove it completely out of the void area. This cannot be emphasized enough: The void egress must be kept open and clear at all times in case an immediate withdrawal from the void becomes necessary.

Support Team

Void expander firefighter

Initial position at mouth of void. A versatile firefighter with a varied range of experience should be assigned the duties of the void expander firefighter, the member of the support team closest to the void entry team (fig. 6–2). This firefighter may be called on to perform the functions of both the entry and support teams. The void expander firefighter's initial position will be at the mouth of the void, from where he or she can pass debris out of the void or pass tools and equipment in or out. This firefighter's position must remain flexible. While waiting to assist other members of the team, the void expander firefighter will attempt to widen the void opening if necessary. Situated at the mouth of the void, this firefighter is also in the best position to relay information from the officer to the void entry team, and vice versa. The void expander firefighter stays in direct contact with the entry team throughout the operation.

Widening the void. If the void entrance is small and confined, the void team officer may decide to widen it and establish better access and egress. If so, the widening operation becomes the responsibility of the void expander firefighter, who is assisted by the support firefighter if needed. The support firefighter makes sure that any material that is removed is taken away from the void entrance. It must be stressed, however, that only in certain conditions will it be safe to widen the access while rescuers are in the void. The officer must carefully evaluate the safety aspects of action such as cutting, moving, or shifting of debris or structural elements that could result in a secondary collapse.

Assisting the void entry team. The void expander firefighter may become an additional member of the void entry team, if conditions warrant. For long voids—if the victim is more than 15 feet away from the void entrance, for example—it improves safety if the void expander firefighter enters the void area. Doing this enables the firefighters to stay in close physical proximity to each other should any problems arise. From this position, the void expander firefighter can assist with debris removal or help with shoring operations.



Fig. 6–2. The void search team operating at a building collapse on 31st Street in New York City. The officer is at the mouth of the void directing operations. The support firefighter has the Stokes basket, and the void expander firefighter is widening the void with the shoring firefighter. They are expanding the void in order to allow better access to rescue a victim being extricated by the void entry firefighter.

Entry team relief. Under the direction of the void team officer, the void expander firefighter is available to relieve one of the void entry firefighters. Usually, the void entry firefighter is the first team member to be relieved, since this position is the most strenuous. Stationed at the mouth of the void, the void expander firefighter is in support mode and, therefore, relatively fresh and in a perfect position to relieve one of the void entry team members if necessary, which is quite often the case.

Support firefighter

Passing back debris. The support firefighter, the second member of the support team, clears debris as it is passed out of the void entrance to an area of safety away from the operation. Usually this debris is passed to other fire personnel who have formed a human chain to quickly take material out of the building. Once removed outside the collapse zone, the debris can be examined by legal authorities, if necessary, without interrupting the search and rescue operations. Larger pieces of debris such as wood and furnishings can be removed by hand. Smaller pieces of debris easily can be placed in buckets and then quickly and efficiently removed from the building. For the sake of efficiency, collapse debris should only be handled once. The objective is to get it clear of the structure the first time it is picked up and moved.

Tool delivery. The support firefighter requests and receives from any tools and equipment needed by the void entry team. This firefighter makes sure that all tools are operational and set up properly before sending them into the void. He or she ensures that hoses and cables have enough slack to make the stretch into the void and do not become entangled in debris.

Assisting in void expansion and shoring. If necessary, the support firefighter assists the void expander firefighter in enlarging the mouth of the void and shoring near the void entrance. The cutting of shoring members generally should be done away from the void entrance. Thus the support firefighter gives the measurements to the cutting team outside the immediate collapse area and coordinates the relay of shoring material from the cutting area to the void entrance, where the material is then fed to the awaiting firefighter. In special cases, the cutting may be done relatively close to the void entrance, in which case the support firefighter can do the cutting and work directly with the void expander firefighter.

It is vital to note that cutting relatively near the void entrance and expanding and shoring the mouth of the void while firefighters are operating inside the void can jeopardize the safety of the operation. When making these decisions, therefore, the team officer must carefully consider the possible safety repercussions. Before making these decisions, the officer must scrutinize a variety of factors, including the size of the collapse, the stability of the debris, the size of the opening, and so forth.

Personnel relief. While monitoring the condition of the team's operating personnel, the void team officer may have the support firefighter relieve a member of the search squad. However, depending on the location and severity of the collapse and the position of the apparatus and equipment, the support squad may be as heavily engaged as the search squad. If this is the case, the officer will have to relieve the entire void search team and substitute a fresh one. The officer must anticipate this situation and be prepared for it.

Tool and equipment firefighter

Tool staging. The third member of the support team, the tool and equipment firefighter, sets up the tool staging area, the point from which all tools and equipment are sent into and received from the collapsed structure. The more organized and knowledgeable about the apparatus this firefighter is, the faster the equipment will get to the proper area in working condition. Therefore, the driver or apparatus operator is usually assigned to this position.

For maximum efficiency, the tool and equipment firefighter should set up as close to the operation as possible while, of course, staying within safety guidelines. A 20-by-40-foot tool staging area would not be considered too large for an average collapse operation. This size of an area provides sufficient room to lay out all the equipment and move several items at once so that personnel picking up and returning equipment do not interfere with each other.

Tool testing. All tools sent into a collapse operation must be examined and tested to make sure they are working properly. Blades or bits should be checked to ensure that they are sharp, properly installed, and sufficiently tightened. Tools with blades should be sent with a backup blade to the void entrance. When the blade gets dull, the replacement can be sent in immediately. The void space is not the place where one should be changing broken or dull bits or blades.

Requesting additional personnel. The tool and equipment firefighter generally needs additional personnel to help set up the tool staging area and unload the tools and equipment off the apparatus. This firefighter must request these firefighters through the void search team officer or the chief in charge (or through other channels of command). Whichever protocol is to be followed, it is up to the tool and equipment firefighter to request and obtain the staffing

needed to get the job done. For smaller collapse rescue operations, two or three additional firefighters may be all that are needed to get the supplies to the collapse area. For extended operations in which numerous tools are needed or the apparatus are not close to the collapse zone (which is typical of most collapse operations), numerous firefighters will most certainly be needed. It is not uncommon to have at least 10 firefighters to accomplish the job properly. The tool and equipment firefighter may have to assign at least one other firefighter to keep a tool log, also. This will help speed up the handing out of tools as well as make it easier to keep track of those tools.

Maintaining the tool log. Tools removed from the apparatus must be recorded in a master tool log along with the following information: the name of the individual requesting the tool, the time of the request, the name of the deliverer of the tool if more than one person is issuing equipment, and the floor or general area to which the tool was sent, if possible. As the tools are returned the following information should be entered into the log: the time the tool was returned, the name of the individual who returned it, and the person to whom it was returned. Because of the confusion and activity typical of operations involving multiple agencies, such as collapses, a tool inventory log is a necessity.



Fig. 6–3. The void entry firefighter (John O'Connell) exiting the void after the successful rescue of a trapped victim. This void was extremely tight, negating the use of fire gear in order to reach the victim. The victim was pinned by debris and had a broken leg, but he recovered successfully.

This is an overview of the considerations that should be addressed in collapse rescue training and in the collapse rescue plan. Regardless of how you organize your collapse rescue team or the names you assign to collapse positions, you cannot expect to function safely and efficiently at a collapse search and rescue operation without ongoing and comprehensive training, experienced members, teamwork, the appropriate equipment, and a sufficient number of on-scene personnel beginning with the early stages of the operation (see fig. 6–3).

Team Concept in Structural Collapse Shoring Operations

Collapse shoring operations, like any collapse operations, must be conducted safely and efficiently. Generally, the shoring material, tools, and equipment are not located close to the collapse area, but just outside the collapse zone in a safe area. This necessitates the formation of the shoring team of six trained firefighters, which is divided into two squads of three members each: the shoring squad, which will perform the actual shoring size-up and erection of the shores, and the cutting squad, which will set up the tool and equipment area and perform the measuring and cutting of the shoring lumber (fig. 6–4). These are some of the guidelines your rescue team can use to establish continuity among your personnel.

Shoring Squad	Cutting Squad
• Shoring Officer • Measuring Firefighter • Shoring Firefighter	• Layout Firefighter • Cutting Firefighter • Tool & Equipment Firefighter

Fig. 6–4. The shoring team is broken up into two squads just like the void search team. The shoring squad works inside, and the cutting squad is outside.

Shoring Team

Any time a department is going to attempt a collapse rescue operation, it should be following the team concept. This ensures maximum supervision and organization, both critical to a safe and successful operation. Personnel who are planning to erect rescue shoring must be organized as a team. In most rescue situations, a six-member team, one of whom is the officer in charge of the team, works rather well. Their job, in conjunction with the incident commander, operations chief, and possible technical help (such as a structural engineer), will be to cut and erect any rescue shoring required, whether inside or outside of the collapsed structure.

Shore assembly squad

It is recommended that the shore assembly squad consist of a shoring officer and two firefighters. In most instances, these three firefighters will be able to erect the shores that are required. Keeping the teams small exposes the fewest personnel to danger. The two firefighters operating with the shoring officer are the measuring firefighter and the shoring firefighter.

Shoring must start from a good, safe area and then work into the bad or damaged area. When the shore assembly squad starts working, the shoring officer will direct the other two squad members and make sure that whatever they need is supplied to them in a timely way. The team will erect one shore at a time, always working from a safe area. The shoring squad firefighters should be relieved and replaced when deemed necessary, at the discretion of the officer in charge. The team's shoring officer should work with a structural engineer who is familiar with shoring and collapse rescue to establish a plan for erecting the shores in a specific order. Generally, the most critical areas will be restabilized first. During the planning stage, the shoring squad members should anticipate their tool and lumber needs, which will give the other personnel time to gather up the necessary materials and have them ready when necessary.

Shoring officer

The shoring officer is in charge of the shoring operation, including both squads. The supervision of the shoring operation is based on the shoring

size-up, this officer's experience, and the department's shoring guidelines. The shoring size-up will not end until all shoring has been installed and secured and the operation is coming to a conclusion. The shoring officer must be in direct charge of the crew. Properly operating teams can safely and efficiently erect rescue shoring in a highly professional manner. Improper organization and coordination can slow the team down and cause the operation to function poorly, possibly with dangerous results. With this in mind, the officer's position has to be flexible, perhaps operating in several different locations to coordinate the shoring operation. The shoring officer needs to be always one step ahead of the team. When erecting a series of shores, the officer must make sure that the area for the next shore all clear, lumber and material are all laid out in advance, and enough equipment is on hand to do the entire job.

It is also very important that the shoring officer confer and coordinate with any *qualified* structural specialist on the scene. Remember, and this is important, that not every engineer knows about building collapse or shoring. Your team should be utilizing only qualified structural engineers who have experience in collapse and shoring operations. The shoring officer and the qualified engineer should be in agreement on the size, design, and placement of any shoring systems they erect. All shoring that the teams erect must be constructed to accepted standards and properly anchored. The shoring officer is responsible for making sure that this happens. A structural specialist can help the officer in this endeavor.

Another one of the shoring officer's responsibilities is to pick the personnel for each team position. These team selections should be made at the response to the incident or preferably at the beginning of the tour. In order to do this properly, the officer must have a thorough knowledge of the training and abilities of all the personnel under the officer's command. The officer must also be cognizant of the technical background of the members, such as skills outside the fire service. This includes construction workers, carpenters, mechanics, engineers, and any related professions that would give the firefighters a decided advantage when constructing rescue shoring.

Obviously, the best carpenters should be measuring and erecting the shores. The firefighters laying out and cutting the shoring materials must have some experience with the appropriate tools and

equipment. Some firefighters feel more comfortable in different positions. For example, someone who is not too proficient in the use of different types of cutting saws, such as a chain saw or a 10¼-inch circular saw, should not be forced to use them. Discuss the assignments with your firefighters and make sure they are willing to accept the job and can do it properly and safely.

The shoring officer, in conjunction with the team members, should decide where the tool and cutting station should be located. A few of the things to consider are setting up in a safe area, access to the tools and materials, and the size of the area needed. In any case, the cutting station must be set up outside the secondary collapse zone. The officer will also have to supervise the step-by-step erection of each shore that goes into position. When several shores are being erected, the officer will have to be positioned in an accessible area in order to answer questions from any of the operations. If the structural specialist has been trained in rescue shoring techniques, then that individual's help may be enlisted if necessary. Remember, the officer must stay several steps ahead of the shore assembly squad, or the operation will slow down, causing problems and delays. The officer should make sure that the area where all the shores are to be erected is cleared and prepared beforehand, if possible. Other firefighters (who are not on the shoring team) can do this job and run back and forth for tools and materials. In this way, your trained and experienced personnel can be properly used for the technical operations that are necessary for the safe completion of the shoring operation.

The shoring officer must communicate to the incident commander the need for additional personnel, if necessary, as soon as possible. The officer must make sure that a safe means of access and egress is available at all times to the crew in case of any unforeseen problems. This area must be at least 4 to 6 feet wide and free of all obstructions in case a rapid exit from the area is needed. This should be one of the officer's primary concerns, for this clear passageway will easily become cluttered very rapidly with tools, materials, and personnel. The proper relief of all the shoring personnel must be monitored on a regular basis. A tired firefighter will get hurt, so at the first sign of fatigue, the firefighter should be replaced. The officer must also determine if the use of more personnel is needed or justified. Simultaneous shoring

operations may need to be done in separate areas. If these operations can be safely accomplished without impacting other operations, then the shoring officer can request another shoring team to be placed in service. Remember, whenever any shoring is erected, someone must be assigned to continuously monitor the shores in case any movement or shifting occurs requiring the shoring to be readjusted. This must be done right up until the conclusion of the incident.

Measuring firefighter

After confirming with the officer the exact location and type of shoring to be constructed, the measuring firefighter will do all the measuring required for the erection of that shoring. This firefighter should stay in direct contact with the layout firefighter (see the cutting team) via portable radio, on a separate tactical channel than the main event. The measuring firefighter will relay all the measurements and lumber sizes to the layout firefighter, who will then measure all the material at the cutting table. The measuring firefighter generally determines how long the shore will be, taking into account what is to be supported and how much room is available to work in. Another very important item to consider is when the use of wedges is called for. Space must be deducted from posts or struts for the application of these wedges before the lumber sizes are requested. This is done to avoid any confusion on the part of the two teams. Whatever number the measurer calls out to the cutting crew will be the size of lumber that the shoring team will receive. No deductions or subtractions will be done by the cutting team. For this reason, the measuring firefighter must carefully think out each move and double check the measurements before calling out the numbers to the layout firefighter. As a rule of thumb, deduct the width of one wedge from the posts or struts to be used to give enough room to properly fit in two wedges married together for the final adjustment. The measuring firefighter will be the lead of the two-member team and will converse directly with the layout firefighter on a secondary radio channel. This will enable the two of them to talk directly without any interference creating possible miscommunication and mistakes. As the measuring firefighter, make sure that you write down all the measurements that you take and send them to the cutting team. This will help keep any confusion to a minimum (which will happen, by the way). Make sure that you call out the measurement that you want and

repeat it. To avoid confusion, have the layout firefighter repeat back to you the information you gave. To make things easy for yourself, many times it is a good idea to draw a simple picture of the shore that you will erect and mark down the measurements on it. This can then be used as a reference point if any confusion arises, and it is especially helpful if numerous shores are being erected. When the measuring has been completed and the shoring materials have been brought in, the measuring firefighter's job will be to assist the shoring firefighter with assembling the shores. Again, to avoid confusion, all measurements should be called out in inches. It has been my experience that this leads to fewer problems.

Some of the tools the measuring firefighter uses include a tape measure, level, pad and pencil, shoring guide book, and lumber crayon.

Shoring firefighter

The second member of the shore assembly squad is the shoring firefighter. One of the main functions of this position is to ready the area to be shored by clearing away debris and obstructions that could interfere with constructing the shore. An area at least 3 feet wider and 3 feet longer than the shore should be cleared of any debris and leveled off. This should be enough to keep the area clear while the shore is being erected. Any debris should be cleared down to either floor level or ground level in the basement area. It is always a good idea to bring a shovel to the work area, preferably a small, square-faced, D-handled type, which is easier to manipulate in tighter areas. The shoring firefighter also will help the measuring firefighter with getting the proper measurements; quite often this will be necessary. The shoring firefighter is usually limited to basically holding the "dummy" end of the tape. When the shoring material is brought in, the nailing of the material is generally done by the shoring firefighter. Making sure that there are enough nails to do the job, as well as all the proper numbers of wedges, gusset plates, and hand tools to assemble the shores, is the responsibility of the shoring firefighter. This too must be taken care of while the measuring firefighter is relaying the measurements to the cutting station.

Some of the tools the shoring firefighter uses include shovels, pneumatic nailers, a square, a fully equipped carpenter's tool pouch, and a pinch bar or nail puller.

Cutting squad

The cutting squad consists of three firefighters: the layout, the cutting, and the tool and equipment firefighters. The first responsibility of these firefighters is to secure an area as close as possible to the collapse operation (but outside the collapse danger zone) to minimize the number of personnel needed to relay the materials to the shoring team. This should be decided in conjunction with the officer in command and the shoring officer. It is not unusual for several companies to be employed moving lumber and tools to the collapse area. As a matter of course, plan on this being the case. The team must clear debris from an area large enough to accommodate the necessary tools, equipment, and lumber that will be needed for the particular operation. Although each operation is unique, any shoring operation will need a specific number of tools and equipment, whether one or 10 shores are erected. An area 12 feet wide by 24 feet long would not be considered large; in fact, this is the size you may want to consider as an average minimum size. An area this size will allow you enough room to place your necessary layout and cutting tools, set up a cutting station, and place some lumber in position to be cut and marked. This area should be plainly marked off, and a minimum number of personnel should be allowed to operate in the area for safety reasons.

Layout firefighter

The layout firefighter is in charge of setting up the cutting station and preparing the materials to be cut. This position is the lead firefighter of the cutting squad and must stay in contact with the shore assembly squad at all times. The layout firefighter notifies the tool and equipment firefighter of the size, length, and amount of lumber needed, based on the information received from the measuring firefighter in the shore assembly squad. Being in direct contact with the measuring firefighter helps reduce the possibility of miscommunication. Generally, the layout firefighter will be on the same radio channel as the measuring firefighter. If necessary, the layout firefighter can contact the shoring officer by switching to the primary radio channel and talk to the officer directly. The layout firefighter measures and lays out the lumber, marking it so that the cutting firefighter can cut it to the correct lengths and at the correct angles.

As layout firefighter, make sure that you understand the numbers and sizes when laying out all the measurements that you received from the measuring firefighter. Always double check and repeat the information that you have been given. This will help eliminate any confusion or misunderstandings that can cause errors. Cutting the wrong size lumber will drastically reduce the efficiency of the operation, costing precious time delays in the erection of the shoring. At that point, a properly sized piece of material will have to be cut again. It is a lot easier and far more efficient if you do not rush and instead take the time to cut the proper size on the first effort. A tried-and-true axiom used in the construction trades for decades, which works perfectly in rescue shoring operations, is measure twice, cut once. If you keep this in mind when working the cutting station, your operation will run smoothly and accurately.

Communication is the key to safe and successful operations. The layout firefighter should always tell the cutting firefighter what sizes are needed and explain why he or she is laying out a particular piece of lumber. The tools will include a tape measure, squares, templates, pencils, lumber crayon, and tool pouch.

Cutting firefighter

The cutting firefighter's responsibilities include setting up the cutting station; cutting the shoring material; and safely operating, maintaining, and handling the cutting tools. This firefighter must also ensure that all blades are sharp and all equipment is in proper working order. The cutting firefighter works directly with the layout firefighter in both setting up the cutting area and cutting the shoring material. Small gas- or electric-powered chain saws can be used. Electric saws are preferred, since they operate more quietly and may be slightly easier to handle. Electric circular saws can also be used; however, to cut 4 × 4 lumber in one pass, a 10¼-inch blade is essential.

The person who is selected to be the cutting firefighter must be able to handle saws and tools and must have experience cutting lumber. An incident is not the place to start to learn how to properly cut building materials. Without the proper precautions, this can be a very dangerous operation. The cutting firefighter should use the saw type most familiar to him or her. This will obviously make things much easier for this firefighter, and thus the cuts should be

more accurate. It is also important that the cutting and the layout firefighters are in full agreement on how the lumber is to be laid out and cut. The cutting firefighter must know for each cut on which side of the line the cut is to be made. Although we are not making pianos, the more accurate the cuts are, the better the rescue shoring will fit, which is our primary concern. The cutting firefighter must be sure that all the cuts are square and neat. Sloppy and out-of-square cuts are not acceptable and will make the shores inefficient and dangerous.

As a cutting firefighter, take your time making the cuts and make sure that you are comfortable, there is enough room to safely work in, and there is enough lighting available in order to see what you are cutting. If you are using an electric circular saw, a guide for the saw can be used to make the cut more accurate. A power miter saw will also make the cuts very accurately, and your life will be a lot simpler, but keep in mind it takes quite a bit of power to supply these tools. Remember to make sure you make the right cut the first time. You do not want to have to cut another piece and hold up the operation.

The cutting firefighter is an important position. One of the more skilled and knowledgeable members should be placed in this position, an experienced carpenter if possible.

Tool and equipment firefighter

The tool and equipment firefighter supervises the removal of tools and equipment from the apparatus to the cutting station or the shore assembly squad. This job generally goes to the apparatus driver or operator. Because so many tools are involved, the help of one or two companies goes a long way toward getting equipment off the rig and to the right location quickly. Remember, the apparatus may be some distance from the collapse area. The equipment firefighter indicates to those who are assisting which tools and equipment are needed and where. This firefighter also keeps an inventory checklist or log sheet so equipment can be easily retrieved at the conclusion of operations. Another major responsibility is to make sure lumber gets to the cutting station in a timely manner. The lumber is sometimes not the easiest thing to procure and get to the site. Once the material is on-site, the tool and equipment firefighter has to make sure it gets to the cutting station as soon as possible. Other

firefighters on the scene can help get the material to the cutting station and the shoring team. This can be a labor-intensive situation, and numerous members will be necessary to accomplish this task in a timely manner.

It is also imperative that the tool and equipment firefighter keep accurate track of where the tools and equipment have been taken and are being used. Since we do not have an unlimited supply of all of the tools, this is very important. In an emergency situation, a specific tool may be required, and it must be accessed immediately. When the rescue team requests that specific tool, the tool and equipment firefighter must know the area, location, and the personnel who are using the tool so it can be quickly acquired if necessary. This can be tracked using one sheet of paper.

Larger Shoring Operations

In some larger collapse operations, a single shoring team may not be able to operate effectively on its own. If this is the situation, then several shoring teams can be deployed instead of just one (fig. 6–5). The shoring team can consist of six members, and the cutting team an additional six members. The commitment of the additional personnel helps the operation proceed more efficiently.

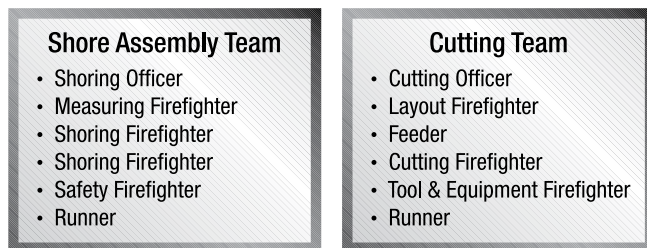


Fig. 6–5. Larger operations call for two teams. Here are the two teams and their positions.

Several teams can be employed to speed up the operation. They may work in the same general area or be located remotely from each other, such as on separate floors. When there is more than one shoring team, a separate cutting team should be established to make the operation continue smoothly. A rough rule of thumb is to establish one cutting team for every three shoring teams. This is an initial guideline.

Since each rescue shoring operation is different, adjustments may have to be made. Keep close watch on the progression of the shoring operation and make your adjustments accordingly. One factor that will affect this will be the proximity of the cutting station to the shoring operations. If it is very close, the cutting team may use more people as cutters and use the runners of the shoring team to carry the materials. If the teams are remote from the cutting station, then the personnel on the cutting team may have to help transfer the materials. This will limit the number of personnel doing the actual cutting and layout. When the operation starts, keep an eye on the availability of the materials for the shoring teams. Check with each team to make sure that materials are arriving on time. If not, adjust the operation accordingly. Remember, team positions are flexible, and they can be adjusted at any given time and in any given situation. In order for the shoring operation to succeed safely and properly, it must progress smoothly and quickly, and any slowdowns in the procedures must be immediately addressed.

Six-member shoring team

The six members of this team are a shoring officer, one measuring firefighter, two shoring firefighters, one safety/assembler firefighter, and one runner. These positions are flexible, given that each operation is different, and distinct situations will arise at each collapse.

Shoring officer

The shoring officer's job and position are basically the same as the shoring officer in the three-member shore assembly squad. However, rather than being in charge of both the shore assembly squad and cutting squad, this officer supervises the six members of the shoring team. The shoring officer may very well be supervising the erection of several shores at once as well as working with the measuring firefighter in the proper positioning of new shores. This officer must constantly be one step ahead of the shoring teams. As firefighters are erecting any of the shores, the shoring officer must have the next shoring system identified and planned out. This officer works with the measuring firefighter in this task when necessary, always anticipating the next moves the team will be making until the completion of the shoring operation.

Measuring firefighter

The job of the measuring firefighter is generally the same as that position in the shore assembly squad. This firefighter will work with the shoring officer in determining the position of the shores for the layout measurements. The officer and the measuring firefighter, after conferring with the structural specialist on the scene, will determine the type and size of the shores that will be necessary to stabilize the remains of the structure. As measuring firefighter, you are responsible for taking the measurements for the materials needed for the shores and writing them down. Relay those measurements as soon as possible to the layout firefighter of the six-member cutting team. Make sure the layout firefighter repeats those numbers to you so no mistakes are made.

It is vital that the proper materials enter the collapse site and are erected quickly. Tell the shoring firefighters exactly where the shore goes and which size lumber goes where. Communication is critical, as with all rescue operations. When you are satisfied that everything has been explained, then move on. Measure for the next shore and stay one step ahead of the shoring firefighters. The operation cannot be slowed down at any point; keeping the measurements going to the layout crew will keep the operation on track.

Shoring firefighters

The two shoring firefighters will do the brunt of the shore assembly. One or both of the shoring firefighters place the shoring lumber together, allowing the safety/assembler firefighter to anchor it together. For example, the two shoring firefighters would hold up the header for a vertical shore, and the safety/assembler would nail it to the ceiling beams. Sometimes two firefighters are not needed to help with the nailing; in this case, the other firefighter will do whatever is necessary to speed the erection of the shores. Their positions are very flexible. For example, one firefighter may be needed to assist the measuring firefighter with clearing the area for the next shore and getting the proper measurements. Or the runner may need help procuring equipment and lumber for the operation, especially if the cutting station is a fair distance away. The two shoring firefighters are responsible for doing whatever is necessary to speed the shoring operation, while remaining under direct supervision of the shoring officer. As in any rescue operation, the

positions are flexible, and they will do whatever it takes to accomplish the tasks at hand. They must anticipate their next moves and be able to work around any obstacles that they may encounter along the way.

Safety/assembler firefighter

The safety/assembler firefighter nails and anchors the shoring systems together. If using a pneumatic or gas-operated nailer, probably only one firefighter will be needed to accomplish this job. This is the preferred method of anchoring any shoring. However, if the nailing has to be done by hand, at least one of the shoring firefighters will most likely have to help the safety/assembler firefighter nail the shore together. If the crews are anchoring the shoring material by hand, then careful consideration must be given to the possibility of movement or vibration occurring when the nails are driven into the lumber. In many cases, when anchoring two pieces together, one firefighter will have to hold the joint together while the other nails it in place. This will help stop the pieces from moving and keep the vibrations to a minimum.

The safety/assembler firefighter, as the name implies, will also be the safety firefighter for the team. As a safety firefighter, while you are waiting for the tools and materials to come into the shoring area, use that time to monitor the safety conditions at and around the shoring site. You should look primarily at the instability of the areas your team will be operating in. Look at the structural elements of the areas in question as well as any connection points that may affect the operation your personnel will be in. Also keep watch for any other operations in the area that may affect your group's working situation. Safety is a major concern and should be everyone's concern at any operation. All personnel should be constantly looking for any signs of changing conditions that may possibly affect the stability of the structure. If you notice any situations developing that can lead to danger, immediately contact your officer. If necessary, evacuate the area also. While the rest of the team is doing their prep work, you should be constantly observing the surrounding conditions and listening to any radio transmission that could affect the building's condition.

When the shoring firefighters are ready to assemble the shores, you will again be the assembler firefighter and will nail the components together. This makes the erection of the shores go rather quickly and

therefore efficiently. After you perform that function, you can then resume your safety responsibilities.

The runner firefighter

The main responsibility of the runner is to get the tools, supplies, and lumber needed to assemble the shores. This firefighter will have to determine where the tool staging area is and will be responsible for transferring the needed tools and materials to the shoring area. The runner will also work together with the six-member cutting team's runner. Ideally, they will be able to bring in the necessary lumber as quickly as possible. However, they may need additional help. If that is the case, then as much help as they need must be assigned to complete the job. The amount of help that will be required will depend on several factors, such as how much shoring is to be done, how large is the lumber required, and how far away from the cutting station is the shoring operation. These are the main questions that should be asked to determine how many personnel may be needed. When multiple teams are operating, it is a good idea for the runners to bring back to the cutting station in writing what size lumber pieces they will need. This will limit the number of possible mistakes, something we cannot afford in this type of rescue operation.

Six-member cutting team

A six-member cutting team may be needed on larger operations. The six-member cutting team consists of the cutting team officer, a layout firefighter, a feeder, a cutting firefighter, a tool and equipment firefighter, and a runner. One or more cutting teams might be needed in a major operation where numerous shores have to be assembled at the same time and extensive shoring operations are required.

With the decision to implement more than one shoring team simultaneously, the need may arise for a cutting team. Some of the criteria that indicate the need for a specific cutting team are the location of the cutting station, the number of shoring teams, the location of the shores in the structure, and the location of the storage of the shoring materials. If the cutting station is located outside the collapse zone (which in most cases would be the safest place), a long distance away from the shoring site is a distinct disadvantage. Obviously, the farther away the cutting station is, the longer it will take to get the tools and materials into

the structure. In addition, several more firefighters may need to be assigned to transporting the shoring lumber and tools to the shoring teams.

When there are more than two shoring teams in operation, it is safe practice to establish at least one cutting team. Usually, one cutting team can handle up to two or three shoring teams, depending on the types of shoring being built and how proficient the shoring teams are at assembling that shoring. When the shoring is located throughout the structure on several floors, additional personnel will be needed to deliver the material throughout the building. These personnel must be assigned to that situation as soon as possible. If your stockpile of material is not located near where it is needed, the same issues as described earlier will apply; logistics and personnel must be implemented to transport the materials to the cutting and shoring stations. Once again, these positions remain relatively the same as those of the three-member cutting squad, with the following differences.

Cutting team officer

The cutting team officer is in charge of all personnel on the team. This officer selects the team positions, as always, taking everyone's specific expertise into account. This is a crucial part of the decision-making process. The officer will, as usual, supervise the team. The team members may, as necessity dictates, be spread out over a sizable area. Coordinating them with the constantly changing conditions found in a collapse situation is complicated. Keeping the cutting operation safe and constantly flowing is the cutting officer's primary concern. Along with the layout firefighter and the cutting firefighter, the officer should coordinate the setting up of the cutting area. Make sure there is enough room for the safe operation of tool and equipment movement as well as specific cutting operations. Wherever cutting tools are being used, safety is the greatest concern. The officer must oversee the proper movement and handling of the tools, lumber, and equipment needed for the cutting station to function properly. It is of utmost importance that enough of each will be supplied; the success of the shoring operations inside the structure depends on it. The anticipated need for specific tools and lumber sizes has to be immediately determined, and a process implemented to have the procurement of those materials accomplished as soon as possible. The officer must also stay one step ahead of the cutting operation and

be able to order more materials and tools before the team runs out of anything. Determining what types of tools and materials will be needed by the shoring teams is a priority. The cutting officer must stay in constant contact with all shoring operations and their officers. Any changes or updates in the shoring teams' positions, types of shores being erected, lumber sizes, or tool requirements have to be immediately relayed to the cutting team officer.

Layout firefighter

The layout firefighter's responsibilities generally remain the same as on the three-member cutting squad. This firefighter stays in direct radio contact with the measuring firefighter if supplying one shoring operation. The two firefighters will converse and make sure properly sized material is cut and delivered into the collapse site. When two or more shoring operations are in progress, it may be difficult for the layout firefighter to stay in contact with the measuring firefighters of the different teams, and some confusion may result. If this is the case, make sure that every radio transmission is distinct and the individuals identify themselves. When transferring the cut material into the structure, make sure the runners have the proper item. They may not always know which piece has been requested next.

Feeder

The firefighter assigned the feeder position will generally be responsible for the stacking and moving of lumber at the cutting station area. This firefighter will interact with all other firefighters on the six-member cutting team. The feeder's main function is to place the lumber in position on the cutting table so that the layout firefighter can do the cutting calculations. The feeder, with help if necessary, should have the lumber laid out in separate stacks. Generally, material should be stacked separately by size; for example, 4 × 4s should not be mixed in with 2 × 4s. The longer lumber should be on the bottom for ease of stacking and proper balance of the load. One other function that the feeder may have is as important as any other on the cutting team, that is, to make sure the cut pieces of scrap lumber are cleaned up immediately. They can quickly become a trip hazard, especially dangerous for the layout and the cutting firefighters. If either one of these members falls and trips, it could easily result

in injury. It is a good idea to have a container set up to safely dispose of the short pieces. The feeder can also remove the material from the cutting table and work with the runners of the shoring teams to get the lumber out to the shoring operations.

Cutting firefighter

The cutting firefighter's responsibilities are the same for both the cutting squad and team. This firefighter must work closely with the layout firefighter at all times. When the situation dictates the use of more than one shoring team, the cutting firefighter will have several responsibilities, mostly safety related. The first is more information exchange and the addition of more firefighters into the cutting area. The size of the cutting area may have to be increased proportionally to the larger operation. The volume of cutting will also increase proportionally, which means that all the firefighters on the cutting team will be working that much harder and faster. As the speed of the operation increases to handle the additional workload, safety considerations increase as well. Safety is a priority in any operation, especially in a collapse situation and at the cutting station in particular. The team members must be constantly aware of each other's positions and whereabouts, especially when the saw is operating. The saws can cause quite a bit of serious damage if they become uncontrolled; they are very dangerous pieces of equipment when not used properly. Bringing lumber and materials in and out of the station area improperly can easily injure someone, too. The cutting station must be a constantly organized operation throughout the entire rescue operation.

Tool and equipment firefighter

During a large, complex operation, the tool and equipment firefighter's responsibility will be increased. This firefighter must anticipate the need for more tools and materials at the cutting station. The cutting firefighter will be using the saw much more frequently and will need the tool maintained accordingly. This must be anticipated and is one of the tool and equipment firefighter's priorities. Without the saw, the lumber will not get cut. In a large operation, the typical department's collection of tools and equipment may be overwhelmed rather quickly. If an extended operation is anticipated, this firefighter should call for additional resources before the teams run out of supplies. When a

large number of supplies is needed, the tool and equipment firefighter should request help from the cutting officer for the additional means to get the necessary tools and equipment to the cutting station.

Runner

The runner should follow the same operational procedures he or she has already been working with. This will limit any possible confusion. The operation can get complicated when the cutting team is feeding more than one shoring team. The layout firefighter must keep track of which shoring operation is receiving the materials. This firefighter must work closely with the runners from both the cutting team and the shoring teams that the cutting station is feeding. The less the lumber is handled, the sooner it gets to the point of shoring, which is where it is needed as quickly as possible. This is where the runner's duties become invaluable.

Training Your Personnel

The most important consideration when establishing a specialized unit is to ensure that the personnel are qualified enough to carry out the functions established in your protocol. Thorough training should begin as soon as the decision is made by your department to organize a team. This training must emphasize the basics of collapse and must be completely understood by all personnel who may be involved in these rescue operations. Training, coordination, and discipline are the hallmarks of an effective rescue operation. All three must be fulfilled for the operation to run smoothly, safely, and expeditiously.

To begin this process, take a complete survey of your response area to determine the type of structures your team may encounter in a collapse operation. Classify the buildings by construction, occupancy hazards, and structural conditions. Most residential and commercial occupancies should be identified, and training should be adapted accordingly.

The next and possibly most important skill that rescuers must learn is how to identify collapse hazards. This type of training must be extensive and should include recognizing warning signs, knowing the correct safety precautions to take, and identifying collapse patterns and voids.

The following section contains a 12-phase outline that can be used as a training guide for your collapse rescue team. However, because rescuers from various areas of the country face different hazards during collapse responses, the outline should be modified where necessary to fit the specific needs of your department. Each phase lists the steps your rescue team will need to take before, on arrival, and during a collapse operation. Remember that this training guideline is a broad outline that can and should be adjusted to your team's particular needs.

This outline covers most collapse operations. Although some of the phases may be just a refresher for your team, others may cover whole new subjects that will require extensive time to learn. In any event, training is the most important factor in determining the safe success of your rescue operation.

Collapses are not everyday occurrences. For that reason, training is that much more important, and understanding and practicing what you may encounter in a collapse operation is the best way to prepare your team. There are no guarantees in any rescue collapse operation, but a comprehensive training program can make your team knowledgeable and more efficient, thereby keeping the odds on your side for a safe conclusion to the incident.

Phase 1. Identification of collapse hazards

Your team members must be able to quickly and confidently identify the hazards they will be encountering. It is very important that this phase of the operation be properly understood, given that the safety of victims and rescuers will depend on the proper on-site size-up. An intensive training program in this subject should be conducted for all members of your team.

Warning signs. On occasion your team will be called to a situation where a structure is unstable. Knowing the possible warning signs of collapse, your team can avoid a potential problem or determine that a building is unstable and evacuate it if necessary. When called to an operation of this type, one of your team's standard operating procedures (SOPs) should be to call the local building department for its technical input on the stability of the structure. Common warning signs that all your personnel should be familiar with include bulging or cracked walls, unusual sounds, sliding plaster or airborne dust, vibration, sagging floors or

roof, and separation of walls from each other or the ceiling. These are all signs of an imminent problem and must be addressed immediately.

Causes of collapse. Knowing the cause of collapse can give you valuable insight in how the structure was affected, how extensive the damage may be, and what the possible hazards may be. Each cause has its own unique set of problems. By being familiar with those problems beforehand, your team will be able to anticipate the complications that may arise and operate that much more efficiently. Some common causes of collapse are explosions, natural disasters, fire-weakened structures, overloaded conditions, improper workmanship, structural failures, and collision impact.

Identifying collapse voids. One of the most important parts of the size-up is identifying the collapse patterns and their accompanying voids. It is not uncommon to have more than one type of collapse pattern in the same structural collapse. This information will give the team excellent insight on where to search first and ultimately a much better chance for the successful rescue of victims. Knowing the classic patterns and where to look first for trapped victims is a must for your search team personnel.

Safety precautions. Safety is of paramount concern in any collapse rescue operation, and any training should include learning proper safety precautions. Some of the most important precautions are shutting down utilities, lighting the area properly, limiting exposed personnel, establishing a danger zone, assigning safety officers where needed, shoring where necessary, implementing proper teamwork techniques, using self-contained breathing apparatus (SCBA) if necessary, monitoring the atmosphere, and limiting any outside interference that may affect your operation. A well-trained safety officer will complement your rescue operations. This officer can keep a watchful eye out when your personnel are fully committed to the rescue operation. This position is a must for any type of structural collapse operation.

Phase 2. Principles of building construction related to building failure

One of the best ways to understand how and why buildings fall down is to understand how they are put together. A thorough understanding of construction

technology will give your rescue team an edge on how the structure will react during and after a collapse.

Construction terminology. Knowing the standard construction terms used in the industry today and the proper application of those terms should be an important part of your training curriculum. It is always a good idea to have everyone on the same “wavelength” when talking about structural building elements. Having knowledge of the proper use of the terms will make it a lot easier to deal with any construction crews or structural engineers whom you may have to work with.

Proper application of loads. Examining and understanding how structural loads are applied to buildings will help the firefighter understand how framing materials are used to support the contents and structure of a building. By having a working knowledge of these principles, your team members will understand how and why the building collapsed or if the remains of the structure will be able to support the new loads that have been suddenly applied to them. This training is a must for any personnel who will be operating in the collapsed structure, and absolute knowledge of this subject is necessary for crews that are erecting any type of shoring.

Building types in your area. By studying the building types in your area, you may be able to anticipate some of the problems you may encounter. By surveying the response area, your team can preplan for possible types of hazardous conditions and choose the types of tools and sizes of material they may need for each possible situation.

Why buildings fall down. Understanding why the building came down in the first place may give you valuable information on the condition of the remaining structure or the type of voids that may have been created. For example, if a gas explosion ripped through the structure, any type of void could be formed, and the ability of the remaining structure to support itself and remain stable enough to safely operate in should be suspect. This is due to the violent forces that have been suddenly applied to the entire building. The reason for the collapse may give you an overall picture of the remaining stability of the structure and what, if any, hazards or secondary collapse potential to expect.

Phase 3. Initial collapse operations

Responding on the initial alarm to a scene of a major collapse operation can be an eye-opening experience. Sorting out the mass confusion is one of the first priorities, a very difficult job indeed. By preplanning some of the initial operations, your team can be familiar with the hazards and will be in a better position to get a handle on the situation.

Initial size-up. When responding to a major collapse operation, one of the most important considerations is the initial size-up. A rapid and thorough size-up is critical in the early minutes of a collapse. It will determine the direction your teams will be go and how your collapse procedures will be implemented. This size-up should be done by everyone involved in the rescue and continue until the operation is over.

Chief officer's responsibilities. The biggest responsibility and problem for the chief is to get control of the situation. This can be an extremely difficult task. Not only will you be dealing with your own personnel, but civilians and several other agencies may be there operating also. Being in charge of the entire operation means the safety of rescue personnel and victims alike will be the chief's responsibility. Do not hesitate to call for reinforcements if you deem it necessary.

Line officer's responsibilities. The line officer's responsibilities will be set by your department's guidelines. However, at all times, you will be responsible for the firefighters directly assigned to you. Because conditions can change very rapidly, you need to be in constant communication with your immediate supervisor. Many times the operation will change as new information is gathered. For this reason, the team must remain flexible and be able to react to any unforeseen situations that develop.

Engine operations. Learn your department's guidelines on the placement of the first-, second-, and third-arriving engines. "Taking hydrants" and stretching enough hoseline to cover the collapse area are your top priorities. Commitment of the personnel and the areas they will cover can be worked out in your collapse rescue guidelines.

Ladder operations. Aerial platforms or tower ladders should have priority to set up in front of a collapsed structure. They can be used as an observation area as well as master stream placement if necessary. One team should have the responsibility of

shutting down all utilities, and the remaining teams should be involved in search and rescue operations.

Technical rescue operations. Coordinating the rescue of trapped victims can be a complicated operation, especially if more than one victim is trapped. Medical and rescue teams should work hand in hand in these situations. Setting up a chain of command for such instances must be preplanned for this type of operation to run smoothly.

Interagency coordination. Several different agencies may be operating at a major collapse situation, including fire, police, medical, utility companies, and contractors with heavy equipment. They all will have different operating procedures, and coordinating their efforts can be difficult. Guidelines and areas of responsibility can be preplanned and discussed prior to any type of incident. Trying to sort this out at the scene of an actual incident will only bring the operation to a halt and could create a major fiasco and embarrassment for all parties involved.

Phase 4. Void search operations

Void size-up. Using the acronym FASTVOIDS (fire, additional collapse potential, structure type and condition, trapped occupants, void type, occupancy type, immediate utility shutdown, day or night, and situation that caused collapse) will give your void rescue team a basic set of guidelines to follow. Of course, these guidelines should be adjusted during size-up to the individual situation.

Search techniques. The proper techniques for searching the entire collapse area and site-specific areas can easily be set up by your department. Many of the search techniques used today can be refined and utilized in collapse operations.

Team operations. Teamwork is an important concept in collapse operations and should be stringently followed. It is the most effective way to operate safely and the most efficient way of utilizing your members. It will also give accountability to your members, affording the team some control.

Team members' assignments. Team assignments give each team member an area of responsibility. Constant direction should not have to be given, wasting precious time. With specific duties for each firefighter, the operation should continue smoothly.

Phase 5. Tools and equipment

Hand tools. The most frequently and intensely used items in your entire tool cache are hand tools. Every firefighter on your team must be proficient in the use of the team's tools in order to bring the operation to a safe and successful conclusion. Hand tools can be broken down into six general groups: measuring, digging, prying, cutting, hammering, and mechanical.

Electric tools. Most carpentry work is done with electric tools, the most common type of power tool. The three main functions of these tools are cutting, drilling, and demolition.

Pneumatic tools. Air-powered tools are valuable for heavy-duty operations and are often more powerful than electric tools. They usually have fewer working parts than electric tools, and as long as they are properly lubricated during operation, they can withstand substantial use. Air tools work well in collapse situations because they operate more quietly than gas-powered tools and are intrinsically safer, a definite plus in hazardous situations. In addition to cutting, drilling, and hammering, pneumatic tools also provide a safe way of lifting heavy objects.

Hydraulic tools. There is a variety of hydraulic tools to choose from, including drills, circular saws, cutoff saws, chain saws, chipping hammers, hammer drills, and impact wrenches. Each tool needs a power unit and two hoses to operate, which can limit the rescuer's mobility. The diamond segmented chain saw is one hydraulic tool that may be worth the trouble, however, because it can cut up to 15 inches of concrete at one time, depending on the model used. If your area has numerous concrete structures, this tool should be part of your inventory. Hand-operated bottle-type jacks with up to 20 tons of capacity are also excellent for working in collapse voids. They can be quickly set up to support tight openings where trapped victims might be located. Hydraulic tools are generally more powerful and quieter than their gas-operated counterparts.

Gas-powered tools. Primarily used for cutting, gas-driven tools can also be used for rotary drilling and breaking up concrete or masonry. Chain saws are excellent for cutting lumber for shoring and for clearing debris from collapsed buildings. Generally, the smaller saws are easier to handle and safer to operate. Rotary saws, 12 inches and larger, are used as the primary roof ventilation saw by many departments. They can be used to cut light steel or concrete and are efficient

for masonry cutting with diamond tip blades. Larger rotary hammers also run on gasoline, but these tools do make a lot of noise and cause vibrations. Fumes may also be a problem, making gas-powered tools unsuitable for interior operations.

Proper handling techniques. The biggest problem and most detrimental to the tools themselves is the improper use and mistreatment of the tools. By teaching the proper procedures and techniques associated with each type of tool and discussing the safety aspects of all the tools, your operation will become more efficient. It will be safer for the tool operator, as well as save wear and tear on the tools themselves. This is the most important part of tool training, a must for all members of your rescue team.

Tool maintenance. The old adage "take care of your tools and they will take care of you" is very true. Tools must be properly maintained and serviced continually during the operation, or they will fail to work efficiently, become dangerous, or cease to function entirely.

Phase 6. High-tech search tools

Thermal. Infrared and pyro-electric are two types of thermal sensors that are available. Have your team test them out to determine which one will be more useful.

A thermal imaging camera, based on the pyro-electric effect, was developed by engineers in Great Britain about a decade ago. This camera is designed to pick up minute variations in the electrical polarization of an object resulting from the difference in temperature between it and the objects around it. This can be a useful device, especially in the dark. You may be able to pick out a human victim at night or inside a dark void that you may not have seen otherwise. Be aware, though, that this is not an X-ray machine. It does not see through anything—it only picks up differences in temperature. If the victim's skin is exposed, then his or her body would be detected. If the body is covered, or coated with a lot of dust and plaster, it may not always be detected. There are numerous thermal imaging cameras on the market today, so your team needs to pick one everyone likes operating with.

Visual. The visual equipment that is available to your team varies from a simple pair of binoculars to sophisticated fiber-optic cameras. A good pair of binoculars can be used outside the collapse zone, in

relative safety, to observe and search the collapse debris or the remaining structure. As collapse equipment goes, this item is relatively inexpensive. Another item that is available and has been used with success is the search cam.

Acoustic. Using sound to pinpoint trapped victims is not a new idea. Listening devices have been around for quite a while. There are several types and designs of acoustic listening devices available for collapse search and rescue, and the price range also varies considerably. This type of tool will work effectively in the right conditions. These tools operate most effectively when the situation is under control and outside noises are kept to a minimum.

Canine. Dogs that are properly trained for this specific type of operation can be used to find possible victim locations. Using dogs will help by speeding up the search operation. However, they are just another tool and cannot be relied upon entirely for victim search. Victims are sometimes missed by dogs. Always search any area thoroughly by hand even after the canines have not indicated the presence of victims.

Advantages. The proper use of any of these tools can speed up the search operation in certain cases. That is just what they are, another tool in your cache; they cannot be totally relied upon as the sole search source in most situations.

Disadvantages. The possible disadvantages of any tool include how often will it be used versus the cost factor, to name just one. This is a decision your team must make on its own.

Phase 7. Initial safety shoring

On most occasions, initial safety shoring must be done, especially when an operation is conducted in the interior of a damaged structure. The need for this type of shoring is based on the safety of your operating personnel. Initial safety shoring is erected quickly to help stabilize an area, while stronger shoring, which will take longer to construct, is being built.

Shoring placement size-up. This size-up consists of the procedures your team will quickly use on what, where, when, and how the initial safety shores will be erected.

Mechanical shores. The different types of mechanical shoring should be discussed, and their various uses to the rescue team should be explored.

They can be erected rather quickly, are extremely substantial, and can support a large amount of weight.

Pneumatic shores. One type of quickly erected initial shore, the pneumatic shore, is versatile and extremely strong. The use of air is usually not needed in collapse operations; however, these shores can be used in trench rescue and vehicle stabilization as well, possibly justifying the expense to your team.

Wood shores. The most common type of shore you will be erecting is the wood shore. These shores do not go up as quickly as the other shores; however, the material is much cheaper, readily accessible, and can be easily left in place if necessary. As a rule, any shoring your team erects will stay up. We do not get involved in the demolition of structures.

Phase 8. Interior shoring

Most of the rescue shoring your team will be erecting will be the interior type. It is used to resupport damaged structural elements from the inside of the building. Interior shoring consists of stabilizing door and window openings, unreliable walls, and structural bearing members.

Shoring size-up. This size-up consists of the procedure in which the shoring officer and the shoring team members evaluate and determine where the shore will be erected, what type of shore will be used, how it is to be constructed, what size of lumber to use, and the spacing requirements. The shoring team will work with the structural specialist assigned to the operation to do this size-up.

Box cribbing. Box cribbing is used extensively in void operations, and it has been used in other situations as well. However, its main purpose is to support structural elements in tight openings or areas of limited access. It is one of the strongest and most stable shores. There are several methods of erecting the cribbing and several different sizes of lumber that can be used.

Diagonal bracing. This type of bracing is easy to erect. Its main purpose is to stabilize any loose or leaning interior or exterior walls.

Window shore. This shore is used to support and stabilize damaged windows and smaller openings in collapsed structures. It is normally erected when access to and egress from a building are needed from a window or opening.

Door shore. The door shore is designed to secure or resupport existing doorways, access ways, and any large openings in a structure's walls. It is mainly used to ensure a safe entry and exit from a building.

Vertical shore. The "dead" shore, as it is also called, is used to stabilize damaged floors and support or replace damaged and unstable walls. It is generally the most common type of shoring your team will erect.

Interior raker shore. The interior raker shore is normally used to support unstable or leaning columns and structurally unsound walls, from the inside of a structure.

Horizontal shore. This shore is used to restabilize existing hallways, thoroughfares, and the like. It is mainly used to secure a safe access for the movement of rescue personnel and any possible victims.

Phase 9. Exterior shoring

The main purpose of exterior shoring is to secure and stabilize a damaged structure or the remains of a structure. This is done to stop any further collapse from occurring or to allow access to and egress from a building for rescue personnel. The placement of exterior shoring can be an extensive and time-consuming operation.

Shoring size-up. This size-up is done to determine where to place your shoring and the type, amount, and size of lumber you will need. By following the size-up in the proper sequence, these questions can be easily and quickly answered.

Exterior raker shore. A commonly used exterior shore, its main purpose is to support a structure's bearing walls that are leaning or have somehow been damaged. Ideally, this will prevent secondary collapse.

Horizontal shore. The exterior horizontal shore is designed to support openings in shaftways, alleys between buildings, and large retaining walls that are adjacent to structures. It is normally constructed of 6 × 6 lumber or larger.

Flying shore. Rarely used, the flying shore can stabilize an exterior wall of one structure against another, a complicated long-term operation using much larger size lumber than your team normally uses.

Tie-back systems. These systems can be used to stabilize a wall leaning outward from the interior. Tie-backs are excellent for use on the upper floors of

a structure when raker shoring is impractical. They usually consist of strong backs and steel cables, bolted down to the existing floors.

Phase 10. Rigging operations

In any major structural collapse situation, the movement and removal of building debris is a large part of the rescue effort. Rigging cranes and mechanical advantage can be employed to help in the removal process when items and debris cannot be moved by hand operations. Your team's training must include at least the basics of the proper techniques and procedures of rigging operations.

Mechanical advantage. A thorough knowledge of the mechanical advantage of rigging will greatly help the rescuers. Moving debris manually can be a difficult and arduous task, which rigging can help alleviate by multiplying the force applied by the rigging operators. Knowing the proper rigging techniques will make your operation run more smoothly and quickly and result in less effort expended by your team members.

Equipment signaling. Knowledge of equipment signaling is a must when the team is going to work with heavy construction equipment. There are basic hand signals that are accepted by the construction industry. For everyone's safety, construction crews and rescue personnel must be on the same wavelength. There are several types of equipment that may wind up at an operation. Proper coordination with the equipment operators must be maintained in order for the job to be completed safely and efficiently.

Knots and splices. Basic knot-tying techniques and proper handling of rope are necessary skills for any collapse operation. Every member must be familiar with the most commonly used knots, and it is a good idea for the team to set up a protocol about which knots to use where.

Wire rope uses. In the construction industry, the use of wire rope slings as lifting devices is almost universal. Everyone on the team who will be working with construction equipment or crews should know how to use these materials properly.

Lifting and hoisting principles. The rescue personnel who are assigned to the rigging operations should know these principles. They must know how to properly rig up objects, determine the right size cable, and position the cranes the right way. If not done

correctly, this can be a very dangerous operation. It must be done by qualified personnel only.

Sling angles and hitches. The proper use of the chokers and safe rigging angles for all slings, synthetic as well as wire rope, are very important. The wrong angle can put a severe strain on the choker, possibly failing it. Knowing when to use the proper hitch is also important. You need to know whether a choker, basket, or vertical pick is the most efficient use of your slings.

Phase 11. Concrete operations

Types of concrete. There are numerous types of concrete in use today. They have different strengths and are used in different structural situations. Stressed and prestressed are two types, and they react differently in collapse scenarios. Your team must be able to identify what type of concrete that they are working with on scene and how to properly handle it.

Cutting techniques. Removing concrete and cutting damaged and undamaged concrete require practice and training. There are several methods that can be used, and several different types of tools that can be employed for this operation. One important operation that all team members must know is the “clean lift-out.” This is done in several ways to access areas where trapped victims may be located.

Specialized tools. There are several concrete breaching tools available, from cutting to sawing to breaking. Each type should be trained on, and it must be determined which tools work the best for each situation. All these tools take practice and proper knowledge to handle efficiently. Included in this category are the many types of torches available for cutting reinforcing steel.

Phase 12. Victim removal

When a victim has been physically reached and is now considered a patient, all the necessary protocols that are in effect in your team’s jurisdiction should be brought into play. There have been numerous discussions on how and when to treat these patients according to the dangerous position they are trapped in. Whatever your department’s jurisdiction has decided should normally be followed. This can sometimes be a tough call as each situation will have its own problems.

Size-up. When you reach the patient and do your initial survey, all decisions will be based upon the severity of entrapment and the condition of the trapped person. Again, all local protocols must be followed and implemented.

Removal techniques. How to properly package and remove the patient from the collapse debris can be a complicated issue. People trapped in deep voids can be difficult to extricate as well as maneuver out of the void areas. The numerous options team members have in packaging and removal must be taught to all personnel. In every situation there will be several different alternatives available to the rescuers for implementation. Training in all the techniques and on all the equipment should be done until each member is comfortable with each technique and piece of equipment.

Identifying crush syndrome. There have been numerous articles written about crush syndrome, and different protocols have been established on how to treat it. Have your medical personnel research this thoroughly for the signs, symptoms, and treatment of this condition. All of your rescue personnel must be aware that anyone trapped for an extended period of time may be subject to this. All injuries should be treated with this in mind.

Recommended Collapse Rescue Course Descriptions

Basic structural collapse operations: 8 hours

This lecture course will provide specialized training in the realm of building collapse rescue. It includes warning signs, collapse causes, void identification, safety precautions, search techniques, team operations, building construction awareness, and initial department operations. Several case studies will be discussed. A tabletop exercise is also included. This class will cover the basics necessary for the beginner to become familiar with the many facets of a structural collapse operation.

Emergency rescue shoring concepts: 8 hours

This lecture class will cover the many concepts and principles of the proper erection of emergency building shoring. The proper size-up, placement, and choices of shores will be described. The proper engineering concepts will be explained, and the fabrication procedures for each shore will be examined. Several case studies will be examined as well. A tabletop scenario concerning the proper placement, size-up, and mitigation of a specific shoring operation will be conducted.

Void search and rescue concepts: 8 hours

This lecture class will cover the many facets of a safe and successful void rescue operation. This is one of the most dangerous operations that is undertaken in fire department emergency response. Team concepts, safety precautions, void identification, hazard abatement, shoring techniques unique to void searching, and victim packaging will be addressed. Several case studies will be discussed, and a tabletop exercise will be conducted.

Building construction related to building failure: 8 hours

This lecture course will cover the many facets of structural erection of buildings. The way structures are erected, how the loads are transferred, definitions, and stress management of the buildings will all be examined. Construction techniques and terminology will be addressed in detail, as well as how the most common types of structures collapse. A tabletop exercise will be conducted at the end of the session.

Engineering concepts for rescue shoring: 4 hours

This class is designed to instruct the students in the basic and advanced engineering concepts that are an extremely important part of the design of shoring systems. The students will learn the proper concepts behind the different angles, the specific nail patterns that are necessary, and how the shores must be loaded properly in order to work effectively. This course will also cover why and how the shoring systems are constructed properly. Knowing the proper concepts and procedures will allow your team to adjust the shoring systems to any possible situation. This 4-hour engineering concept course is a must for operations- and technician-level responders.

Safety and survival in structural collapse operations: 8 hours

This lecture and interactive class will outline all of the necessary concepts your team will need to conduct a safe and effective rescue operation in one of the most unstable environments they will ever encounter. Rapid intervention teams, team concepts, and tool requirements will be discussed. All the safety issues you may encounter will be addressed and identified. Several tabletop exercises will be conducted to enable the student to grasp the proper rescue techniques in use today.

Hands-On Training Courses

Tool and equipment use in collapse operations: 16 hours

This class will have the students identify the proper uses as well as the proper maintenance necessary to handle their rescue cache efficiently. How to use each tool effectively will be discussed and demonstrated. Types of blades, motors, generators, hand tools, and the like will all be part of the two-day exercise. The students will all handle and properly use each tool in the collapse rescue cache. This is a very important class for the novice rescue team to take.

Interior shoring hands-on training: 16 hours

This is a two-day class designed to thoroughly familiarize the student with the proper interior shoring techniques needed to safely construct the types of interior shores needed to conduct safe rescue operations. This is an intensive hands-on course, and the students will be tested on the proper erection of the various shores.

Exterior shoring hands-on training: 16 hours

This is a two-day class designed to thoroughly familiarize the student with the proper exterior shoring techniques needed to safely construct the types of exterior shores needed to conduct safe rescue operations and stabilize the exterior of the structure. This is an intensive hands-on course, and the students will be tested on the proper erection of the various shores needed to accomplish this task.

Void search and rescue hands-on training: 16 hours

This is a two-day class with intensive void search hands-on training. The students will be subjected to operations in several void simulators. Team concepts, proper shoring techniques, safety operations, and size-up will be examined. Several actual rescue simulations will be conducted; the students will extricate victims throughout the two days of scenarios.

Lifting and moving of objects in urban search and rescue (US&R) operations: 16 hours

This lecture and hands-on course is designed to teach the rescue responder the basic techniques of lifting and moving heavy objects, especially by simple methods utilizing leverage. Different types of levers are discussed thoroughly, as well as the basics of mechanical advantage, fulcrums, and pulley systems. The students will be given numerous practical evolutions that will test their physical skills as well as the knowledge gained in the morning lecture.

US&R heavy lifting and rigging: 32 hours

This lecture and intense hands-on training course will cover all the phases of rigging needed to run a successful US&R building collapse incident. A crane, props, and site will be necessary to conduct this course. Slings, crane use and placement, safe rigging procedures, center of gravity, and all advanced aspects of proper and safe rigging practices will be demonstrated during the course.

Breaching and breaking of concrete: 16 hours

Concrete properties, types, and materials will be thoroughly examined and discussed. The various techniques of breaching concrete as well as cutting rebar and the various methods of removing sections of concrete will be demonstrated. Several types of cutting tools and equipment will be needed, and the proper use of these tools will be demonstrated. The students will cut, breach, and break concrete in a vertical and horizontal plane.

Advanced emergency shoring operations: 40 hours

This course is the culmination of all the previous training plus the addition of several new shores not previously shown, as well as an additional lecture class supporting the new concepts. This class will also have extensive hands-on erection of the new shores as well as several stations on the variations of shoring systems that we anticipate will occur at live operations. The shoring of racked openings and sloped floors will also be part of the training.

Collapse rescue training: 40 hours

This course will bring your rescue team up to operations level training according to the requirements in NFPA 1670 and 1006. Your team will also get the latest Federal Emergency Management Agency (FEMA) US&R specialist training. The training will consist of a 40-hour intensive lecture and hands-on training course. This covers all the material you will need to properly perform an emergency rescue shoring operation.

Day 1. This will consist of lectures on all phases of the collapse rescue procedures necessary to perform the operation safely and effectively. Case studies will also be addressed as well as a comprehensive size-up.

Day 2. This will be the initial hands-on day. Exterior shoring will be erected, including the solid-sole raker, split-sole raker, double raker shore, flying shore, and flying raker shore. Their anchoring and bracing systems will also be examined.

Day 3. Interior shoring will be erected. Each student will erect a series of predetermined shores, including window, door, vertical, pneumatic, horizontal, and their variations.

Day 4. This day will consist of the basics of void shoring and searching techniques. T shores, box cribbing, and sloped-floor shores will be erected. The proper teamwork and breaching and cutting procedures in void situations will be demonstrated. All the principles necessary for the safe rescue of trapped victims will be addressed.

Day 5. This day will consist of a live exercise in a structure, ideally partially damaged or collapsed. The students will erect every shore from the previous week's worth of training in a practical environment. This is the culmination of the entire week's training in a live hands-on situation. All the principles will be applied throughout the day.

Technician Level Collapse Course and FEMA Rescue Specialist Equivalent Course

80-hour course: 8-day class

Course description: 80 hours of basic, operations-level, and technician-level collapse rescue FEMA-equivalent training. The course includes all the necessary lectures on safety, dangers, Occupational Safety and Health Administration (OSHA) requirements, and FEMA requirements. Hands-on training will be conducted in shoring, lifting and moving, and concrete breaching and breaking using the latest FEMA rescue specialist curriculum. Safety and proper procedures will be emphasized throughout the training.

Certification: FEMA-equivalent certificate, NFPA 1670 and 1006 technician equivalent, OSHA compliant.

Day 1: Lecture and tool station

08:00–08:30	Introductions and administrative issues
08:30–09:30	Safety
09:45–11:45	Structural engineering systems
12:00–13:00	Lunch
13:00–17:00	Tool lab rotations a. Torches b. Gasoline-powered tools c. Stanley® hydraulics and electric tools d. Pneumatic tools, nailer, and anchoring stations
17:15–18:00	Tool cleanup and critique

Hands-on training stations

Day 2+3

08:00–18:00	Practical station rotations: Shoring
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Day 4+5

08:00–18:00	Practical station rotations: Breaking, breaching, and burning
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Day 6+7

08:00–18:00	Practical station rotations: Lifting and rigging
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Day 8

08:00–09:30	Written test and practical exercise
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Shoring practical exercise stations

Day 2: 10 hours

08:00–08:30	Introduction and safety lecture	
08:45–11:00	Station 1	Shoring lecture
11:15–12:30	Station 2	Double raker
12:30–13:30	Lunch	
13:30–14:45	Station 3	Raker anchor and bracing
15:00–16:15	Station 4	Split-sole raker shore
16:30–17:45	Station 5	Solid-sole raker shore
17:45–18:30	Cleanup and critique	

Day 3: 10 Hours

08:00–08:30	Introduction and safety lecture	
08:45–11:00	Station 1	Vertical shore
11:15–12:30	Station 2	Laced post
12:30–13:30	Lunch	
13:30–14:45	Station 3	Sloped-floor shore
15:00–16:15	Station 4	Window and door shore
16:30–17:45	Station 5	T shore, double T shore, cribbing
17:45–18:30	Cleanup and critique	

Day 2

Station 1: Lecture

The instructor will give the lecture and answer questions from the students on the subject of rescue shoring. The instructor will also outline the next two days' activities.

Station 2: Double raker shore

The double raker shore is used where walls are leaning and either broken or have heavy debris behind the wall, which may fail the wall at any time. It can also be used for shores designed for support above the second story.

Station objectives

Properly erect the double raker shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Be able to properly anchor the shore in any given situation.

Determine the proper angles and the necessary steps to cut those angles.

Be aware of the inherent dangers involved with the use of this type of shore.

Students will erect two of these shores both with different insertion points and at 45° and 60° angles.

Station 3: Raker anchor and bracing

This station will concentrate on the various bracing and anchoring methods needed to properly secure the different types of raker shores we will be erecting. This station will also cover flying rakers and the proper methods for cutting and determining the angles used for all the shores.

Station objectives

Properly erect raker shore bracing in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the bracing in any given situation.

Be able to erect the most common types of variations of the bracing.

Be able to properly anchor the various shores in any given situation.

Determine the proper angles and the necessary steps to cut those angles.

Be aware of the inherent dangers involved with the misuse or inappropriate anchoring of the various shoring systems.

Students will anchor down rakers with at least four different types of anchors. They will brace a series of rakers with two horizontals and three horizontals with the proper X bracing included.

Students will also erect the flying raker shore at this station.

Station 4: Split-sole raker

The split-sole raker shore is used to support damaged or leaning walls, including exterior, bearing, and nonbearing. They can be erected in several styles; however, they must be erected in pairs to be considered stable. Split-sole rakers are generally used where the bearing for the shore will be in earth or if a large amount of debris is blocking access to the base of the wall in question.

Station objectives

Properly erect a split-sole raker shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Be able to properly anchor the shore in earth situations and into concrete.

Determine the proper angles and the necessary steps to cut those angles.

Be aware of the inherent dangers involved with the use of this type of shore.

Students will erect a split-sole raker into an earth situation and erect one in front of a wall with debris piled at least 3 feet high.

Station 5: Solid-sole raker

The solid-sole raker shore is used to support damaged or leaning walls, whether interior or exterior, bearing or nonbearing. They can be erected in several styles; however, they must be erected in pairs to be considered stable.

Station objectives

Properly erect a solid-sole raker shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Be able to properly anchor the shore in various situations.

Determine the proper angles and the necessary steps to cut those angles.

Students will erect the solid-sole raker with a minimum insertion point of 9 feet 6 inches. One is to be erected on an earth situation and have the load properly distributed.

Day 3

Station 1: Vertical shore and horizontal shore

The most common shore you will normally erect in a collapse scenario is the vertical shore. Thorough knowledge of the erection of this shore is an absolute must. In contrast, the horizontal shore is used to stabilize damaged passageways and is normally constructed in larger structures.

Station objectives

Properly erect the vertical shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Know how to brace and properly anchor the shore to the structure.

Make sure all nail patterns are done properly.

Students will erect several of these shores, minimum of four posts each, and at least one with a sloped ceiling situation.

Students will erect a three-post horizontal shore.

Station 2: Laced post shore

The laced post shore is one of the strongest and most stable shores your team can erect. Generally constructed of 4 × 4s or 6 × 6s, it is excellent for stand-alone shoring situations.

Station objectives

Properly erect the laced post shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Know how to brace and properly anchor the shore to the structure.

Make sure all nail patterns are done properly.

The students will erect a 4 × 4 and a 6 × 6 laced post, at different widths.

Station 3: Sloped-floor shore

The sloped-floor shore can be used in void areas where the use of box cribbing is impractical or unsafe. It can be constructed of larger dimensional material and can support quite a bit of weight. The shore must be erected in two segments in order for it to be considered stable.

Station objectives

Properly erect the sloped-floor shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Be able to properly anchor the shore in various situations.

Determine the proper angles and the necessary steps to cut those angles.

The students will erect two shores at different heights, one friction and one perpendicular type.

Station 4: Window and door shore

This station will concentrate on the proper erection of window and door shores. The various methods of installing these shores will be shown, and the positions of the shores related to racked openings will also be covered.

Station objectives

Properly erect the window and door shores in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Be able to erect the most common types of variations of the shore.

Know how to brace and properly anchor the shore to the structure.

Make sure all nail patterns are done properly.

Be able to erect these shores in racked openings.

Students will erect both types of shores in a square, racked, and large opening.

Station 5: T shore, double T shore, cribbing

This station is designed to show the students the two main methods of using temporary shoring. This will include the T shore and the double T shore. The basics of box cribbing in a collapsed environment will also be covered. Efforts will be guided in the proper step-by-step erection of the various shores and their proper positioning in a collapse environment.

Station objectives

Properly erect any shore in the correct sequence.

Be able to determine the proper lumber size needed in any given situation.

Be able to determine the most efficient location for the shore in any given situation.

Understand the principles behind the most common types of shores.

Be able to properly anchor any type of shoring in a given situation.

Determine the proper area to place the temporary shores.

Answer any and all questions the students may have on any shoring techniques or procedures.

Students will erect a T shore, double T shore, and box cribbing in various situations.

Concrete breaching and breaking and burning

Day 4

08:00–09:45	Station 1	Concrete lecture
10:00–12:00	Station 2	Horizontal breach
12:00–13:00	Lunch	
13:00–15:00	Station 3	Vertical breach
15:15–17:15	Station 4	Cutting and burning
17:15–18:00	Cleanup and critique	

Day 5

08:00–10:00	Station 1	Stitch drilling plunge cutting
10:15–12:15	Station 2	Dirty breach
12:15–13:15	Lunch	
13:00–15:00	Station 3	Clean lift-out rescue
15:15–17:15	Station 4	Pipe cutting
17:15–18:00	Cleanup and critique	

Station 2: Horizontal breach

Clean lift-out rescue

Step cut

Dirty breach

Station objectives

Demonstrate inspection hole.

Demonstrate a dirty breach.

Demonstrate setting anchor bolts.

Demonstrate step cut, lift-out, cribbing, and anchor bar.

Demonstrate step cut and lift-out using bevel cut.

Station 3: Vertical breach

Clean lift-out rescue

Stitch cut

Dirty breach

Station objectives

Demonstrate inspection hole.

Demonstrate a dirty breach.

Demonstrate stitch cut using drills.

Demonstrate stitch cut using Stanley® DS11 plunge cut.

Demonstrate anchor bolt placement.

Demonstrate belay device for lowering cutout.

Station 4: Cutting and burning

Piercing cut

Line cut

Cutting tensioned cable

Station objectives

Demonstrate piercing cut with exothermic torch.

Demonstrate line cut with exothermic torch.

Demonstrate piercing cut with oxyacetylene, MAPP, or gasoline torch.

Demonstrate line cut with oxyacetylene, MAPP, or gasoline torch.

Demonstrate cutting tensioned cable using oxyacetylene, MAPP, or gasoline torch.

Demonstrate cutting I-beam with oxyacetylene, MAPP, or gasoline torch.

Demonstrate cutting I-beam with exothermic torch.

Lifting and moving practical exercise stations**Day 6**

08:00–11:45	Station 1	Lift and move lecture
12:00–13:00	Lunch	
13:00–15:00	Station 3	Manual lifting and moving
15:15–17:15	Station 4	Lifting and stabilization, air bags
17:15–18:00	Cleanup and critique	

Day 7

08:00–10:00	Station 1	Crane operations
10:15–12:15	Station 2	Vertical lifting
12:15–13:15	Lunch	
13:00–15:00	Station 3	Gantry operations
15:15–17:15	Station 4	Unstable lifts
17:15–18:00	Cleanup and critique	

Station 1: Manual lifting and moving

Station objectives

- Explain and demonstrate mechanical advantage.
- Explain the three classes of levers.
- Demonstrate the use of simple machines.
- Explain the efficiency of inclined planes.
- Describe the two types of pulley configurations.
- Demonstrate lifting a slab of concrete.
- Demonstrate moving a slab across rough terrain.
- Demonstrate lowering a slab.

Station 2: Lifting and stabilization with air bags

Station objectives

- Calculate the weights of common materials.
- Explain and demonstrate the use of air bags.
- Demonstrate stabilizing unstable objects.
- Demonstrate lifting and moving objects with air bags.
- Demonstrate victim removal.
- Demonstrate lowering objects with air bags.

Station 3: Crane operations, vertical rigging, and lifting

Station objectives

- Explain the use of anchor systems, anchor failure considerations, and proper anchor spacing.
- Demonstrate concrete anchoring systems and attachment points.
- Explain and demonstrate the proper use of wire ropes, wire rope fittings, end terminations, and tighteners.
- Explain and demonstrate nylon load slings and attachment points.
- Explain and demonstrate the use of chain rigging.
- Demonstrate the use of chokers, shackles, and slip and clevis hooks.
- Determine the effects of critical angles as they relate to lifting and moving objects.
- Demonstrate knowledge of crane types and crane nomenclature.
- Demonstrate crane hand signals.
- Demonstrate the ability to cut rebar and debris with oxyacetylene.

Practical exercise

Day 8

08:00–08:30 Team assignments and safety briefing

08:30–16:00 Practical exercise

12:15–13:15 Lunch on the fly

16:00–18:00 Cleanup, test, and critique

The final day of the training will be a full hands-on training with the stations where all the techniques were taught in the previous seven days. The exercises will concentrate on team concepts, organizational skills, shoring, breaching and breaking of concrete, as well as lifting and moving of materials both by hand and with cranes. At the end of the day, there will be a two-hour critique and written test on the previous week's training sessions.

These are just some of the courses your department's firefighters should be taking in order to be adequately trained to respond safely to a structural collapse incident. Remember, without proper training, your personnel will be at a distinct disadvantage responding to these incidents. Their safety, as well as the safety of any civilians involved in the incident, will be at stake. Make sure your people are properly trained and ready to go.

7

Tools and Equipment Needed for Structural Collapse Operations

The many and varied tools your rescue team will need can be classified into several general categories: hand-operated, electric, battery-operated, pneumatic, gasoline-powered, generators, hydraulic, and miscellaneous. Each category has its advantages and disadvantages depending on the type of tool and the situation in which it will be used. The proper use and handling of the various hand tools you will be using in collapse rescue operations are essential to a safe and successful conclusion to your team's response and should be part of your team's training requirements long before any rescue operations will be attempted. It is a definite plus to your department if firefighters are required to be proficient in the safe operation of these tools before being assigned to the structural collapse response team. By making this a requirement, training time will be reduced, and your department will save considerable time and expense. Note that because each situation is different and each occupancy may require specialized tools or equipment, the tools listed are not inclusive. These are some of the more common tools used in collapse rescues, and by no means all the tools you could possibly use.

Hand Tools

Hand tools will be the most frequently and intensely used items in your entire tool cache. Every firefighter on your team must be proficient in the use of all these tools in order to bring your operation to a safe and successful conclusion. Hand tools can be broken down into six general groups: measuring tools, levels, carpenter's squares, cutting tools, hammering tools, mechanical tools, digging tools, and prying tools.

Measuring tools

Measuring tools can also be referred to as layout tools (fig. 7-1). The inclusion of these tools in your tool cache is a definite must; the erection of emergency shoring cannot be done without them.

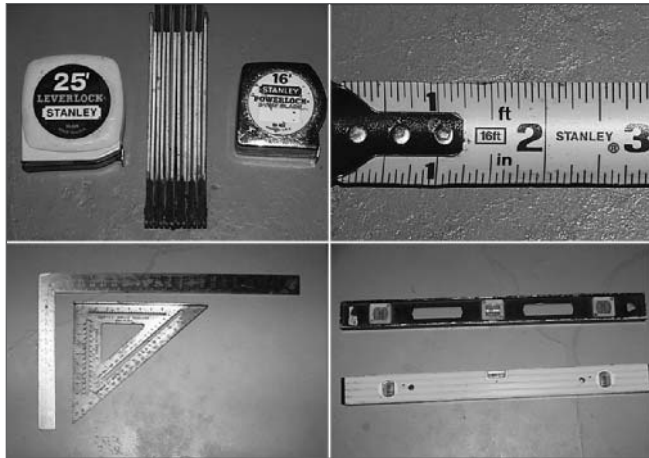


Fig. 7-1. Top left: A 25- and 16-ft tape measure with a 6-ft folding carpenter's rule in the middle. Top right: A measuring tape with a 1-inch blade and a single read tape. This is one of the best tapes to use. It can be easily read in the rain or at night and will not confuse the operator with all kinds of different numbers. Bottom left: Two of the more common squares, the 24-inch framing square and the smaller easier to use "speed" square. These are handheld and very accurate. Bottom right: A few types of levels, including an I-beam design and box-beam design. The box beam will stand up better to shaking and bumping in the apparatus during response. The 6-inch torpedo level (not shown) is also excellent for working in the field, because it does not take up a lot of room and is very portable.

Rules. Mechanical tools generally consist of folding wood rules with a one-way brass slide for extended measuring up to 6 inches. There are two general sizes, 6 and 8 feet. The 6-foot size is normally used because it is easy to handle. Many professional carpenters refuse to use anything but these rules because of their accuracy compared to tape measures. These rules are normally graduated in inches and sixteenths of an inch along both edges, front and back. They work extremely well when exact measurements between two solid points in an opening, such as a doorway or window frame, are called for. Make sure your team purchases the carpenter's rule; there are also rules designed for the spacing of bricks by masonry contractors. Masonry rules have different graduations from the carpenter's rule, and the use of this type of rule will throw your measurements way off. Folding rules are compact and can easily fit into a regular size pocket.

Tape measures. There are numerous sizes and different styles of tape measures available. These measures are versatile, durable, and compact, and they can quickly be brought into use. Of the many choices available, the best suited for collapse rescue shoring are 16- or 25-foot tape measures. Some important

features the tapes should include are an easily retractable blade and a power locking device that will enable the blade to stay extended while operating hands-free. The inclusion of both of these features will make operations with the tapes go faster and more smoothly. The size and style of the retractable blade are also very important. The best type for rescue use is a 1-inch-wide blade that is slightly curved. This size and type of blade can be fed out approximately 7 feet past the tape while still holding its shape. This feature makes the tool an excellent item to use when measuring in and around hard-to-reach places, typically what we deal with in collapse scenarios. The blade should have large clear numbers on it. Tapes with metric measurements and standard feet and inch graduations on the same face of the blade can be confusing. Most of the time we will not be working in ideal conditions. Envision a collapse occurring at 3 a.m. in the pouring rain. Visibility certainly will not be at an optimum, especially for us those of us who cannot see as well as we used too. At least one tape should be included with each tool pouch; ideally, each member involved in the erection of the rescue shoring should have a tape. A couple of 50- and 100-foot tapes should also be included.

Laser measures. A relatively new type of measuring device that uses high-tech laser technology to do remote measurements is called a laser measure. Although the concept is not new, the accuracy of these tools is now adequate for our rescue uses today. The main advantage of this tool is that in a collapse situation you can measure distances without being in a dangerous area. The ability to remotely measure spaces and lengths without entering the danger area is extremely helpful for our rescue purposes. Another good point is that they are compact, portable, and battery operated, making them easy to bring into action at an incident. Higher quality instruments are accurate to $\frac{3}{16}$ inch at 150 feet, more than close enough for our needs. Inside a structure, laser measures work great; outside a structure, depending on where the sun is, they can be more difficult to see. As with all the tools we deal with, there are numerous brands, styles, models, and price ranges to choose from.

Levels

Levels are irreplaceable for precision work, especially when monitoring damaged walls and structures. They can quickly be utilized to check that the shoring your rescue team is erecting is plumb and

level. (The term *plumb* is used to describe the position of level in the vertical plane, such as posts in a dead shore or window and door shores.)

Avongard. The Avongard brand Calibrated Crack Monitor is used to monitor cracks in any type of wall: wood, masonry, or concrete. It is used by engineers to monitor damaged walls by documenting any movement in the cracks caused by undue stress to the structural walls or floors. It consists of two pieces of 1/8-inch-thick plastic, 4 inches long by 1 1/8 inches wide. The bottom is made of white plastic with a 1 1/2-by 3/4-inch rectangle near the edge. The rectangle is calibrated the same on both sides and the top and bottom; in this way, the tool can be used in either position. There is also a box grid inside the rectangle.

Smart level. A tool that was used effectively during the operation in Oklahoma City after the bombing of the Murrah Federal Building in 1995 was a level with a digital liquid crystal display (LCD) readout, known as a “smart level.” This tool is a digital electronic level that reads all angles through 360°. It will display these measurements in four modes: angle, slope, pitch, and a simulated bubble. It comes in three sizes, 24, 48, and 78 inches. The tool used at this incident was the 24-inch size. The smart level is constructed of aircraft-grade aluminum that is triangular with beveled ends, quite different from normal rectangular levels. The triangular shape, with its broad base and narrow top, permits the level to be placed securely on flat surface, preventing it from easily tipping over or falling, while its narrow end makes it easy to grip. The ends are beveled to permit easy maneuverability in tight, angled places if necessary.

The main difference between a smart level and a conventional level is the sensor module. The module consists of an on/off button, mode button, reset button, hold/range button, and an LCD screen. The on/off button is used to activate the sensor and will display the current angle in the mode and range that was previously selected. The mode button is used to select any of four ways of measuring angles, as described in the previous paragraph. The reset button is the key to keeping the smart level accurate. Whenever you are using a level for accuracy, you should make sure it is working properly. By using a two-step procedure after pressing the reset button, your level will be properly calibrated. The hold/range button has a dual purpose: The hold function is used if you need to take a measurement in an unreadable position, and the readout will

freeze the output so you will be able to see it after the level has been moved. The range function enables you to use two levels of accuracy. Range 1 is for accuracy up to 1/10 degree, and range 2 is for 2/10 degree. The LCD has a numerical readout for each mode selected and shows which range and mode the tool is in at any given time. Another excellent function of this tool is that any angle can be set as a reference point. By calibrating the level that a specific angle will read zero, the level will tell you if the angle is moving in either direction and by how much. In Oklahoma City, smart levels were attached to several columns, zeroed, and monitored from a safe distance for any movement. This provided an excellent way to constantly detect if any movement was occurring. The many functions of this tool make it well qualified for this type of rescue operation.

Carpenter's squares

Various types of carpenter's framing squares are another necessity for collapse shoring operations (fig. 7-2). The 2-ft steel square, for example, is used to lay out lengths and angles of raker shores.

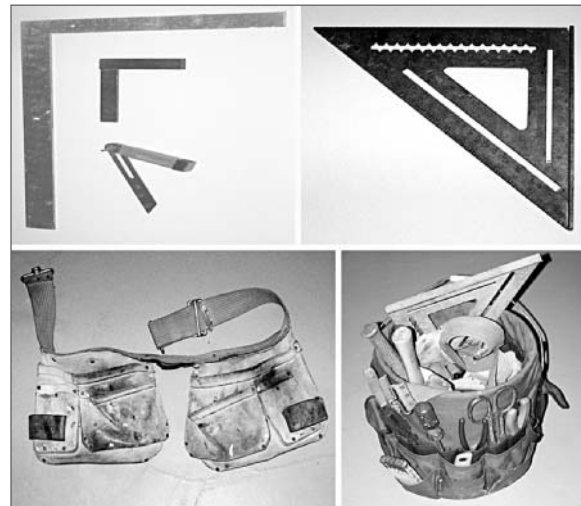


Fig. 7-2. Top left: Three types of squares. The framing square and try square are excellent for cutting and laying out angles, and the T bevel is used for acquiring angles in position. All are very useful in rescue shoring and lumber cutting. Top right: The speed square, another versatile measuring tool, comes in two sizes, 7 and 12 inches. The larger size is shown. Lower left: A carpenter's tool pouch has numerous pockets for tools and nails and allows you to hang your hammer or wrench on your belt. Lower right: the shoring tool bucket has almost all you need for the typical shoring job. Bring the pail inside so you can have easy access to your tools when erecting your shores.

Combination square. This tool can be used for the same purposes as the ordinary try square (described later in this chapter). However, it differs from the try square in that the head can be made to slide along the blade and clamp at any desired location. The sliding of the head is accomplished by means of a central groove in the blade that acts as a guide, enabling the head to travel anywhere along the blade. This groove is etched into the entire length of the square, allowing the blade to be completely withdrawn and used separately as a ruler if the need arises. Also located in the head of the square is a spirit level, which enables the tool to also be used as a simple level. Since the blade can be easily moved in the head, the combination square makes a good marking gauge. This is accomplished by setting the head at the proper location and clamping it there. The entire combination square can then be slid along the edge of the lumber just like an ordinary gauge. Most of these types of squares also have scribes placed in the head of the square for ease of marking accurately. When laying out lumber, the combination square may be used to scribe lines at miter angles as well as at right angles, because one edge of the square head is at a 45° angle. This tool is good for use as a gauge or for marking right angles when lumber has to be cut square.

Sliding T bevel square. The T bevel is a try square with a sliding adjustable blade that can be set at any angle to the handle. The handle is generally made of hardwood, and the adjustable blade is steel. The blade is slotted to allow for linear adjustment and the insertion of a screw pin or pivot clamp, the latter being located at the end of the handle. After the blade has been adjusted to the particular angle you are seeking, it is secured in position by tightening the screw pin or the lever on the pivot. This action compresses the sides of the slotted handle together while firmly gripping the blade in position.

This tool is useful for copying existing angles and transferring them to your rescue shoring. It can save a lot of guesswork on the part of your shoring crew.

Steel square. In almost all building construction work, the steel square, also known as a framing or rafter square, is an invaluable tool for measuring and determining angles. It is most commonly called a framing square because of its various scales and tables, which are used extensively in house framing and building construction.

The steel square consists of two main parts, the tongue and the body (or blade, as it is also called). The tongue is the shorter and narrower part, usually 16 inches long and 1½ inches wide. The body or blade generally is 24 inches long and 2 inches wide. The point at which the tongue and body meet on the outside edge of the square is called the heel. The face of the square is the side on which the manufacturer's name is stamped. It is also the side that is visible to you when you hold the body in your left hand and the tongue in your right hand. The back of the square will be the side opposite the face. As with any tool, it pays to buy a high-quality product; the best squares have their tables and scales etched into the metal, making them the most wear resistant. A square with the tables painted on does not wear well. The numbers quickly wear off with use, rendering the square ineffective as a measuring device.

A good-quality square has six scales and tables. These are a rafter or framing table, an Essex table, a brace table, an inch scale, an octagon scale, and a diagonal scale. The rafter table and the inch scale are the two main items we use and are described next.

Rafter table. This table will always be found on the face of the square, on the body. It is normally used to determine the lengths of common, hip, valley, and jack rafters. It also determines the angles at which they must be cut to fit properly to the ridge board and top plate for roof framing. It is invaluable not only for determining the lengths of rake shores but also for laying out the angles needed for these shores. The rafter table consists of six lines of figures whose uses are scribed on the left end of the body. The first line provides the lengths of common rafters per foot run. The second line gives the lengths of hip and valley rafters per foot run. The third line gives the length of the first jack rafter and the differences in length of the adjoining jack rafters at 16 inches on center. The fourth line gives the length of the first jack rafter and the differences in length of adjoining jack rafters, spaced at 24-inch intervals. The fifth line provides the figure to be used to determine the edge bevel for the side cuts of jack rafters. The sixth line gives the number of the edge bevel for side cuts of hip and valley rafters.

Inch scale. On both the body and tongue, along the inside and outside edges of the square, inches are graduated in eighths, tenths, twelfths, and sixteenths. On the square's face, the outside edge of the body and tongue is graduated in sixteenths. The inside edge of

both sides of the face is graduated in eighths of an inch. On the back of the body, the outside edge is graduated in twelfths, while the inside edge is broken down into sixteenths. The back of the tongue on the outside edge is also broken down into twelfths, and the inside edge is graduated in tenths. These scales are used for measuring and laying out work to precise dimensions.

Try square. This tool is a 90°, or right angle, standard square used for marking or testing to make sure your work is square. The origin of the name presumably comes from its use for testing milled stock for square. The ordinary try square used by carpenters consists of a steel blade that is set at a right angle to the inside face of the stock in which it is held. The stock is generally made of wood with a brass or steel face for protection. The common try square has a blade 6 to 15 inches long. The stock is generally about ½ inch thick, and the blade is set in the middle. This allows the steel blade to be laid on the surface of the wood, while the stock is seated firmly against the lumber. The try square is used mostly for getting a square edge for making lumber cuts.

Speed square. Another type of square that has been developed recently is known as a “speed” square or “quick” square, depending on which manufacturer you purchase the tool from. It was developed to simplify framing of roof rafters in building construction. The speed square uses a one-number method of determining the pitch, instead of the two-number method currently used with the carpenter’s framing square.

The speed square is usually available in two sizes. Generally, the smaller size is easier to handle, which will make it a bit better for use in collapse rescue situations. Basically the square is a right triangle, with the base and altitude congruent at 7¼ inches. A ⅛-inch scale is along one edge; the other edge has a T bar. Along the hypotenuse of the square are graduations for degrees, common rafters, and hip and valley rafters. The T bar enables the speed square to be placed against any piece of lumber and locked into the edge so it will not shift. As a result, it makes an excellent guide for a circular saw at 90° and 45°, two of the most common angles we will be using in collapse rescue work.

If you decide to use the 45° angle consistently in your erection of raker shoring, this tool should be one of your top choices. It will save a lot of time and possibly eliminate mistakes when measuring the 45° angle. One drawback of this square is that you cannot use it to

determine the lengths of the rakes; you will have to rely on some of the other methods available to you.

Cutting tools

When they are found in collapse debris, wire lath, piping, bolts, rods, and cable may have to be cut. Small handsaws, such as a 6- or 8-point cross-cut type, are best for cutting wood in collapse void operations. Hacksaws, bolt cutters, and pipe cutters can also be used to cut material out of the way if necessary. Razor knives, hatchets, and axes are other tools that can be used for a variety of tasks and should be included in your cutting tool inventory.

Hammering tools

Hammers are versatile and widely used in structural collapse operations. There are literally dozens of different applications for which tool would be ideal. A carpenter’s 22- or 24-ounce straight claw (or rip claw) steel-shank framing hammer is an excellent tool for any type of shoring operation. There are numerous styles and types of hand hammers available to your rescue team; steel-shanked with plastic coating and graphite shank are two common types that will work well and stand up to the punishment firefighters are known to give tools in rescue operations. The weights just mentioned are heavy enough to drive nails effectively, yet light enough to be used in extended operations without fatiguing your personnel. The length of the handle should be around 15 inches. Handle lengths longer than that also work well; however, they are more difficult to control for people who do not use hammers for a living. Have your team members pick out the type of hammer they feel the most comfortable with. They will work more efficiently if they are using tools they have confidence in.

Hand-drilling hammers. These hammers are also known as “lump” hammers. They generally range in size from 3 to 5 lbs. There are no claws on these tools; they have driving heads on both ends, excellent when just a little more weight is needed than a framing hammer can give. Commonly used for driving large pins, wedges, tent stakes and breaking up light masonry.

Mechanical tools

This group of tools consists of various types of wrenches, sockets, pliers, screwdrivers, chisels, staple guns, and sheet-metal cutters. Mechanical tools can be used to maintain your other equipment and tighten up loose nuts or bolts, forming an important part of your everyday operations. They are especially useful for the continual maintenance of all your power tools and equipment.



Fig. 7-3. Top left: Three types of handsaws: a hacksaw to cut metal, a keyhole saw to cut holes in wood, and a carpenter's handsaw to cut plywood and dimensional lumber. Top right: Two straight claw hammers: one with a wooden handle, and the other with a fiberglass handle. There are numerous types and sizes of hammers. For those members of your team who are not carpenters, you are better off with a metal shank handle, which does not break as easily. Lower left: An angle finder, which is an excellent tool for determining the angles of leaning floors and walls. The good thing about this tool is that you do not have to transfer it to other firefighters; just give them the angle number, saving a step and some time. Lower right: A group of pliers: gripping, cutting, and holding. Each one has a different use, and a good number of these should be on hand in your tool box.

Digging tools

Shovels are the main component of this group. They come in several combinations of round, pointed, square, or flat. The pointed shovel is good for breaking up and digging in soil or removing large pieces of debris, and the square shovel is most effective when moving excavated soil or fine debris. Another excellent digging tool is the folding shovel or trenching tool, which can be used when working in confined areas and where debris has to be removed from the area

around a victim. When excavating in hard soil, a pick or heavy digging bar can be used first to loosen up the ground, and then rescuers can use shovels to remove loose material.

Prying tools

The main function of prying tools is to pry lumber apart, pull nails, and lift sections of collapse debris. Pinch or crow bars with curved heads are excellent for prying sections of lumber apart. They come in various sizes, and they can be easily carried into collapse operations. Nail pullers, such as the cat's paw and the Stanley® Wonder Bar®, are generally smaller and come in handy, because it is easier to pull out the nails than fight them. The larger and heavier pin or wrecking bars should be used for lifting sections of debris.

Electric Tools

The most common type of power tool is the electric tool (fig. 7-4). Most carpentry work is done with electric tools. The three main functions of these tools are cutting, drilling, and demolition.



Fig. 7-4. Top left: A portable power miter box/chop saw. This tool is excellent for cutting angles and shoring lumber. Top right: A 10 1/4-inch heavy-duty circular saw can cut 4 × 4 lumber in one pass. Bottom left: The reciprocating saw (a popular brand is Sawzall®) is one of the most versatile tools you can have in a collapse operation. It is excellent for cutting in tight places as well as cutting wood or light metal. Bottom right: The gas-operated chain saw has many uses, including cutting wood for shoring or void searching and cutting through floors or roofs. It comes in various sizes and bar lengths, electric or battery operated.

Cutting

Whenever shoring is constructed, electric circular saws will be part of the operation. There are several sizes and types of electric saws, but worm-driven saws tend to be more powerful and withstand abuse better. The decision on which type and size of electric cutting tool is necessary should be made by the firefighters who will be using them. The tools the rescuers are most comfortable with usually work the best. Saws with carbide tip blades are generally better for collapse operations, and there are several types to choose from.

When working in void search operations and shoring operations, the most versatile cutting tool is the reciprocating saw. This saw can make cuts in hard-to-reach places, and depending on the type of blade in use, it can cut wood, metal, and some plastics. The electric chain saw is another excellent cutting tool. It creates far less noise and vibration than its gas counterpart, making it safer to use in collapsed areas. Large miter or chop saws can also be used if extensive cutting is anticipated. When equipped with 14-inch blades, these saws can cut raker shore angles on 4 × 4s in one step.

Drilling

Different types of electric drills are available for making holes in masonry for anchors or inserting search probes. Hammer drills with two positions, drill and hammer drill, are the most versatile and can be used on wood, concrete, or masonry. Heavy-duty screw guns are beneficial because they cause far less vibration than hammers do, and so they are often used in sensitive shoring operations. The higher torque and lower rpm models are recommended for structural collapse work.

Demolition

Electric demolition hammers are good for breaking up masonry brick, block, and concrete and are effective for light demolition work (fig. 7-5). Some of the smaller models also have a hammer drill option, making them twice as useful.

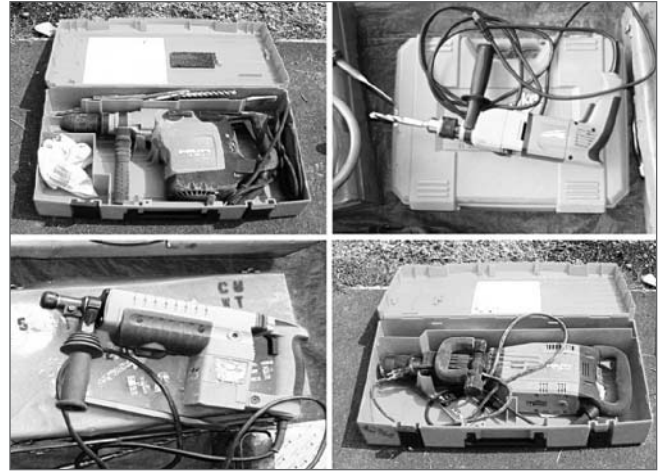


Fig. 7-5. Top left: An electric rotary demolition hammer. This tool is both a drill and hammer drill, and it is excellent for boring holes in wood or concrete. Generally, you need a long extension cord with it, so make sure you use the proper size. Without the right amperage and voltage, it will not work properly and can be damaged. Top right: A medium-duty hammer drill, which is great for drilling holes in concrete less than ¾ inch. It can be used as a regular drill as well. Lower left: A bigger, more heavy-duty version of a hammer drill, good for stitch-cutting concrete. Lower right: An electric demo hammer. This tool has numerous bits, which make it versatile, and it can cut through thin concrete with relative ease. Being electric, this demo hammer runs more quietly, is lighter, and does not give off fumes like gasoline tools.

Battery-Operated Tools

The advantage of battery-operated tools is that they can be brought into play right away (fig. 7-6). However, they still have several drawbacks. They run down quickly under heavy loads and generally do not have the higher torque needed for extended collapse operations. That being said, research and development continue to improve battery life, and so now many battery-operated tools are viable choices in a collapse response. They can be and have been used with success. Just make sure to have a lot of charged batteries on hand and a portable quick charger at the site to replenish your supply.

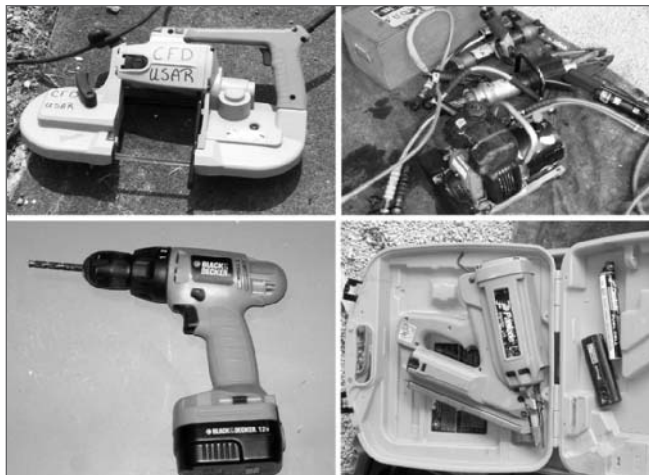


Fig. 7-6. Top left: The portable band saw, though not often used, is one tool that when you need it, you have to have it. It is one of the few tools you will have access to in any cache that can cut through stainless steel, and it can operate in a space only 6 inches wide. This is not something many cutting tools can do, except a Sawzall. Top right: A portable hydraulic tool power unit, great to run smaller hydraulic cutters and spreaders, can be easily put into operation. Bottom left: A battery-operated drill is good enough for drilling small holes into thin metal and wood. You will need backup batteries for continued use. Bottom right: A gas-driven power nailer, used for shoring and nailing operations, is very portable and easy to use.

Pneumatic Tools

Air-powered tools are valuable for heavy-duty operations and are often more powerful than electric tools (fig. 7-7). They usually have fewer working parts than electric tools, and as long as they are properly lubricated during operation, they can withstand substantial use. Air tools work well in collapse situations because they operate more quietly than gas-powered tools, and generally they are intrinsically safer. In addition to cutting, drilling, and hammering, pneumatic tools also provide a safe way of lifting heavy objects.

Cutting

There are several types of air-operated cutting tools, including reciprocating saws, grinders, circular saws, and small rotary cutoff saws. Some of these tools can be used in unique situations, including void operations.



Fig. 7-7. Two methods to support and move debris within different areas of the structure. On the left is a Paratech® pneumatic strut fitted with two 12 × 12-inch hinged bases. You can use these struts with air in a collapse if necessary, usually to reach a height you cannot get to by hand. However, do not use more than 50 lbs of air to set this strut. On the right are typical high-pressure maxi-force air bags. These are perfect to use to lift an object off a pinned victim.

Drilling

Rotary hammers, hand drills, and larger rock drills are high-powered tools that can be used for heavy-duty operations. Rotary hammers have two positions, rotary hammer and either rotary or hammer only, depending on which brand you purchase. They operate at a much lower rpm than hammer drills, enabling them to be used with larger bits and on heavier materials. Rock drills are strictly heavy-duty rotary hammers used for setting anchors several feet into solid rock. They can also quickly drill large-diameter holes into thick reinforced concrete.

Hammering

Several pneumatic hammering tools are available, from small chippers to jackhammers to heavy-duty pavement breakers. The type of building construction and the response area of your team will determine what tools you will need to purchase. If your response area includes a large urban region or a heavy industrial complex with large masonry and concrete structures, the need for the heavy-duty jackhammers and pavement breakers will be greater.

Pneumatic nailers

Another tool brought over from the construction trades that has been in use for the last decade or so is the air or pneumatic nailer. It has some major safety advantages over conventional hammers for use in rescue shoring. The major factor is the tool's ability to drive nails without any impact reaction from the tool. This eliminates any possible disturbance of the material being shored or the area around the shoring material, either of which could cause secondary collapse problems. Another factor to consider is the amount of time that is saved when these nailers are used. It is much quicker to erect any type of shoring using air nailers as opposed to hand nailing, as well as being less fatiguing for the rescue personnel who are constructing the emergency shoring.

There are several brands of pneumatic nailers on the market. The brand for your team should be determined by the rescue personnel who will be using the tool. There are also two types of nailers: the "stick" nailer and the coil nailer. These are references to the type of nail magazine that the tool uses; the stick or straight nailer uses a flat line of nails that are fed into a straight sleeve. The coil nailer uses a large circular coil of nails that uncoil as they feed into the nailer. There are pros and cons to each type of nailer; this is one decision your team will have to make after testing both types of nailer. Try to use only the clips with the full heads, because they hold more than the ½-head nails. The average pneumatic nailer can run on pressures anywhere from 70 to 120 psi, with 100 psi being the norm for typical nailing jobs.

Lifting bags

Lifting can be accomplished by using either low-, medium-, or high-pressure air bags. Low-pressure bags come in a variety of sizes, will conform to various shapes, and will move or support heavy loads. Large sections of collapsed walls with rubble and debris on top can be safely supported with this type of bag. High-pressure bags also come in various sizes, from 6 inches by 6 inches up to 36 inches by 36 inches and are excellent for making small, localized lifts. They are extremely valuable in void search operations and have been used successfully by several fire departments to free trapped victims from collapse rubble.

Another type of pneumatic device is the air shore or rescue strut. These shores are made of an aluminum alloy, are 3 or 3½ inches in diameter, and are used for stabilizing collapse debris and shoring purposes.

Pneumatic rescue struts

When entering into a building collapse operation, it is imperative to take as many safety precautions as possible. The more stable you can make the remaining structure, the safer your operations will be. Erecting rescue shoring in collapsed structures is an inherently risky business, and you must do everything possible to put the safety factors on your side. One of the fastest ways to accomplish this is by using specially designed support systems.

Several types of mechanical and pneumatic shoring systems available today have been adapted for use in rescue operations. One system in particular is very versatile and can be used in various building collapse situations as well as several types shoring and rescue operations. This factor is a major plus for departments with a limited budget. This system gives your rescue team a choice of two securing devices: an acme threaded strut and a self-locking strut.

Self-locking strut. The distinctive feature of the self-locking strut is that it locks automatically in an extended position. Its special locking feature, a double row ball-lock coupling, does not require a person to manually lock it in place, and there are no safety locking pins to install by hand. The hands-free locking feature allows the rescue team to extend and lock the strut from a remote location, if necessary.

Taking down and repositioning the strut can be accomplished more safely than the same operation with some other types of struts. The locking mechanism can be released by removing the load pressure and pulling a release ring. If for some reason the load shifts or if further collapse occurs, a rescue team member needs only to let go of the release ring, and the strut will immediately lock into place again, stopping the debris from shifting further.

Acme threaded strut. The distinctive feature of the acme threaded strut in this collapse rescue support system is that it allows for extremely soft placement in most collapse rescue operations. It can be brought to and gently tightened at any point under a load. The strut is secured in place with a large nut, which extends with the shaft, which the user manually screws down

and locks against the tube. Taking down the acme threaded strut can be accomplished as safely as taking down the self-locking strut: Remove the load pressure and manually twist the acme nut, and the locking nut will be released. If debris shifts while the strut is being lowered, the firefighter simply lets go of the acme nut, and the shore will lock in place, resupporting the load.

Strut extensions. The system also contains three rigid strut extensions, 12, 24, and 36 inches long, constructed of 3-inch aircraft aluminum alloy tubing. These extensions are designed to allow rescue personnel to add length to either strut type, multiplying support capabilities and applications in building collapse situations. Each strut can be used as a rigid support device if the need arises.

Bases and fittings. Thanks to a specially designed adapter called the extension converter, any of the system's bases and end plates may be attached to either end of the strut extensions to create a strong and rigid support device. Numerous bases and connectors are available for the rescue strut systems already discussed, making them very versatile systems. They can be used for building collapse, trench rescue, and vehicle extrication, to name just a few of the operations for which they are suited. Some of the bases and plates are described next.

3-inch standard base. This is a simple 3-inch diameter cap 2 inches high with a $\frac{1}{4}$ -inch pull and a twist-locking pin. Covering both the strut base and the end of the shaft, the standard base protects the strut ends during simple bracing operations.

Rigid base. A 6×6 -inch rigid base with a nonskid grooved surface was developed to provide greater stability than a standard base. This base works well on solid surfaces and when the shore will be used at right angles to the object that is to be braced.

Swivel base. A fitting with a 6×6 -inch square base that can swivel 20° in any direction is used when the items to be braced are not in direct alignment. This is a versatile base that can be used in many different situations.

Cone point base. The cone base is the standard base with a $\frac{3}{4}$ -inch pointed cone in its center. It is used primarily for holding the struts at a slight angle against smooth surfaces such as the sheet-metal skin of an automobile.

Hinged baseplate. Designed to be used with the rescue strut system, the hinged baseplate rotates 90° in one direction, making the struts available as an initial safety rake shore at 45° .

4 × 4-inch channel base. This bracket, specially designed for shoring operations, can be used on the base of the strut or the end of the shaft. It will lock on to a section of 4×4 lumber to which it can be anchored with nails or screws.

6 × 6-inch channel base. This is designed to be used with larger lumber operations, 6×6 -inch specifically, for trench rescue and in larger buildings where more substantial shoring may be necessary.

V base. A 3×3 -inch cylindrical fitting with a 90° V shape approximately 1-inch deep in its center, this bracket is used for stabilizing anything with an angle or corner, such as a tractor trailer leaning after an accident or a beam with a square edge in a building collapse.

T plate. This T-shaped fitting has a lip and a return that can be used to hang the strut for hands-free operation. Such a situation may occur in a trench cave-in, where the walls have to be rebraced before personnel can enter the excavation.

Gasoline-Powered Tools

Primarily used for cutting, gas-driven tools can also be used for rotary drilling and breaking up concrete or masonry (fig. 7–8). Chain saws are excellent for cutting lumber meant for shoring and clearing debris from collapsed buildings. Generally, smaller saws are easier to handle and safer to operate. Rotary saws, 12 inches and larger, are used as primary roof ventilation saws by many departments. They can be used to cut light steel or concrete and are efficient for masonry cutting when using diamond tip blades. Larger rotary hammers also run on gasoline, but these tools make a lot of noise and cause vibrations. Fumes may also be a problem, making gas-powered tools unsuitable for interior operations.



Fig. 7-8. Top left: A gasoline-operated concrete cutting chain saw. The advantages are easier setup and no hoses. The disadvantages are that it is loud and produces fumes. Top right: A hydraulic concrete cutting chain saw is compact and lightweight, but the hydraulics give it a lot of muscle. It needs a separate power unit and heavy hoses to work. Bottom left: A gas-operated rotary saw. This saw can be used to cut metal, wood, or concrete, as shown here, using the right blade for the job. The disadvantages are that gas saws are very loud and give off fumes in the confined areas of collapsed structures. Bottom right: A hydraulic rotary saw is quieter and has a lot of torque.

Generators

There are several types of generators, and they are available in numerous shapes and sizes (fig. 7-9). Larger capacity generators can run several tools or lights at the same time and, for safety reasons such as weight and maneuverability, should be kept outside the collapse zone. Keep in mind, though, that the greater the generator's output, the larger and heavier it becomes. Additionally, because small generators are more versatile than larger generators and can be brought closer to an operation, it is a good idea to always have at least one small generator on hand. A small generator is capable of running one moderately powered light or one medium-duty tool, such as a Sawzall, making your operation a little easier. Regardless of their size, all generators should be operated on a level surface and grounded for safety reasons. Some of the features your department should look for when purchasing a generator are automatic low oil shutoff, ground fault interrupter (GFI) circuit breakers, electronic ignition, and spark arresting mufflers. Be sure to evaluate several different types and brands

before determining which one is best suited to your team's needs.



Fig. 7-9. A portable gas-operated generator on a wheeled carriage, making it much easier for one person to move into and out of position. It also has an easy on-off switch, multiple plugs, and circuit breakers.

Hydraulic Tools

Hydraulic tools include drills, circular saws, cutoff saws, chain saws, chipping hammers, hammer drills, and impact wrenches (fig. 7-10). Each tool needs a power unit and two hoses to operate, which can limit the rescuer's mobility. The diamond segmented chain saw is one hydraulic tool that may be worth the trouble, though, because it can cut up to 15 inches of concrete at a time, depending on the model used. If your response area has numerous concrete structures, this tool should be part of your inventory. Hand-operated bottle-type jacks with up to 10 tons of capacity are also excellent for working in collapse voids. They can be quickly set up to support tight openings where trapped victims are located. Hydraulic tools are generally more powerful and quieter than their gas-operated counterparts. These tools are used primarily for breaching and breaking concrete and masonry.

Hydraulic jacks

An addition to the Paratech system is a 10-ton hydraulic ram with a 4-inch lifting stroke and a separate power pack with a 6-foot hose. The ram can be used in several collapse situations as well as retrieval

systems for shores under pressure. A coupling on the bottom of the ram accepts any of the rescue struts, and a fitting on the top accepts all bases and connectors. It is small enough to be easily maneuvered in a collapse void and used as a temporary support for damaged or unstable structural elements. There are also various sizes, types, and brands of hand-pump hydraulic jacks. The low-profile jacks are generally the best suited to collapse rescue operations, and 4, 6, 8, and 10 tons work well. In special cases, they may be able to gently lift certain collapse debris pinning a trapped victim, freeing the victim from the rubble.

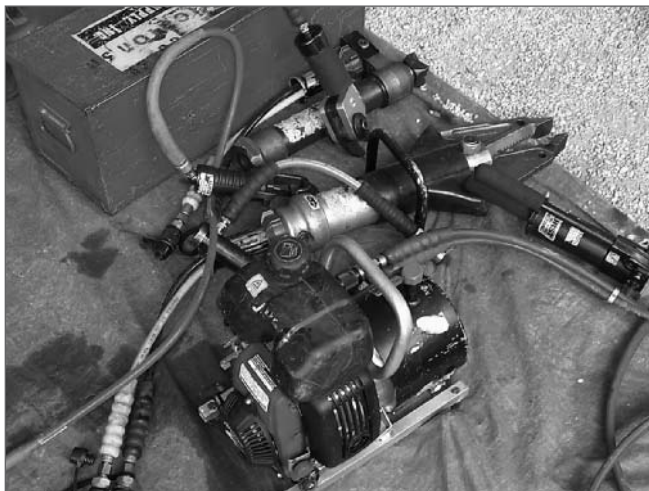


Fig. 7–10. Three types of hydraulic breaking and drilling tools. These tools are very powerful and have few working parts to contend with. They come with a varied number of bits and blades for dozens of uses. The drawbacks are that they are heavy, you need to know how to use the tools properly, and the hydraulic hoses are always lying in the work area.

Miscellaneous Tools

Some other tools that can be helpful to your operation are power-actuated drive tools, oxyacetylene torches, exothermic torches, surveyor's transits, and various rigging equipment.

High-Tech Search Tools

Advancements in technology over the last several years have found their way into the field of search and rescue (fig. 7–11). Unfortunately, fire services have not kept pace with advanced technology as well as

they should have. A large part of the problem is the enormous expense involved in research and development of new equipment. However, these tools may become readily available in the near future.



Fig. 7–11. Top left: An acoustical listening device. This particular model has six separate sensors that can be placed in strategic positions to listen for possible victims. Top right: The search cam, a very good device for visual inspection of voids and holes not accessible by physical means. Bottom left: A handheld portable video inspection system. This one is modular, enabling either the camera or the head to be interchanged. Bottom right: A thermal imaging camera. This is a handheld model with a pistol grip. There are other models available with a palm grip or helmet mounted, so your department should determine which one is best for your team.

The following sections describe several types of high-tech search tools available at this time, grouped into categories by their main functions: thermal, visual, and acoustic.

Thermal

There are several methods for detecting sources of heat, such as infrared and pyro-electric. Both find differences between the temperatures of objects and their surroundings. For example, if live victims are trapped, their body heat can easily be picked up amid the lower temperature of the surrounding debris. This method is excellent at night when visibility is poor. However, one drawback of these devices is that they cannot locate victims who are trapped behind a solid object. A victim could be trapped behind a partition wall, for example, but these tools would not be able to alert you to his or her presence.

Thermal imaging camera. Based on the pyro-electric effect, the thermal imaging camera was developed in the 1980s by engineers from Great Britain. This camera can pick up minute variations in the electric polarization of an object resulting from the difference in temperature between it and the objects around it. By differentiating objects by their thermal temperature, the camera is able to “see” through smoke and darkness. It enables the user to identify fire sources or the images of overcome victims much faster than conventional means.

Thermal imaging cameras now come in several different sizes and styles. The container is waterproof and sealed to conform to specifications for use in flammable atmospheres. The display is a cathode ray tube surrounded by a protective hood. It is a handheld, battery-operated instrument, and the weight varies by manufacturer. It will last up to a couple of hours on one set of batteries.

This camera can sense a living person from up to 200 feet away. It is ideal for use in darkness; however, it cannot see through objects. In heavy smoke or darkness, the camera will be able to distinguish objects by their thermal differences, but it will not “see” past obstructions such as concrete and masonry. Even drywall and glass will block some readings.

Visual

Fiber-optics and video are two ways that images can be transmitted through probes back to monitors that an operator can study. These camera devices can be used for examining voids that are unreachable by search and rescue teams. The images will help you determine if a specific area has to be searched further and if extensive debris handling and removal operations need to be undertaken.

Search camera. The mobile search camera, which can be operated by one firefighter, is a highly technical system designed to locate trapped victims in building collapse situations. The search system combines a miniature video camera with a sensitive microphone. Rescuers can use a search camera to examine collapse voids and listen for victims who may be trapped inside of voids, even if the void access is too small for firefighters to physically enter.

The thermal imaging system consists of three main parts: the search probe, the chest monitor, and the component pack. The search probe is made up of a

telescoping pole with the camera housing and control handle attached on opposite ends. The telescoping pole, consisting of four sections, can collapse to a length of 32 inches and can be extended beyond 7 feet. The dustproof and water-resistant camera housing contains the camera, the microphone, the light, and the speaker element and is connected to the probe by a two-way articulating joint. This construction allows the camera housing to rotate more than 180° to the right or left and is remotely controlled from the probe's handle. The light and audio systems also are digitally controlled by switches on the handle. The telescoping search probe allows a search team firefighter to insert the camera head through void holes as small as 2 inches in diameter. The firefighter then looks for any visible signs of trapped victims on the chest-mounted video monitor and listens through the headphones. The integrated two-way communications system allows the rescue firefighter to talk directly with any possible victims.

The video system comprises a high-resolution video camera and a monitor. Light is provided by a variable intensity lamp system, which allows the video system to operate in areas of total darkness. The camera's most effective viewing distance is from 6 inches to 20 feet. The chest-mounted monitor features a black-and-white screen measuring 7 inches diagonally. It enables the search team firefighters to easily determine what is happening by manipulating the probe. The monitor is enclosed in a pouch equipped with quick-release buckles that are attached to the component pack harness.

The audio system consists of a sensitive microphone with an amplifier. The firefighter operating the tool can wear headphones with a boom microphone attached to them. A speaker element is attached to the camera housing at the end of the probe, enabling two-way communication with survivors. The component pack contains a sealed lead acid battery, good for four hours of continuous use, along with the unit's electrical subsystems. It is housed in a harness worn on the back and is equipped with shoulder and waist straps. For ease of operation, the chest monitor attached to this harness is fully adjustable.

Acoustic

Several different types of listening devices have been developed, and some even have filters to minimize outside noise interference. Most of these tools have several sensors or probes to insert into the collapse rubble, and an operator can listen on a set of headphones for any noises that might be caused by trapped victims. One drawback of these devices is the difficulty in eliminating background interference, which can be considerable even on units with filters.

These high-tech tools are sensitive pieces of equipment that require specialized training, or damage can result. They also take practice to learn to use properly.

Other Equipment

Sawhorses

One quick and inexpensive method of constructing a set of sawhorses is by utilizing the material that you normally have on hand. This type of sawhorse takes up very little room and can be either sealed or painted, whichever you prefer. It is a good idea to paint your department's initials on it for identification purposes. These horses can be constructed of $\frac{3}{4}$ -inch plywood 36 inches high by 36 inches wide. The size can vary depending on your team's preference. A 36-inch-wide, heavy-duty piano hinge can be screwed in along the top, and a handle can be cut into both pieces in the center. The handle should be approximately 3 inches down from the top, 2 inches deep and 5 inches wide. This size should be able to be comfortably grabbed by the average person with gloves on. A chain 24 inches long should be screwed into both inside areas 3 or 4 inches up from the bottom of the horses. This will allow the horses to be opened sufficiently for effective stabilization. Along the bottom of the horses, you can cut out the center of both pieces 18 inches, 9 inches either side of center, and this will leave you 9 inches on both ends for feet. Come up 3 inches when you cut out the center, and this should give you enough room. Or you can just buy one of several types on the market. Make sure you buy an even number of them, though.

Lifting and pulling

At some point in your collapse operations, you will be lifting or pulling debris, lumber, wall sections, furniture, appliances, and the like. The tools shown in figure 7–12 are just what you need to quickly accomplish this. Although your personnel should be trained in crane and heavy-equipment operations, those types of equipment are not always readily available and could take time to arrive and set up. Your team needs to have the capability to move objects with mechanical advantage immediately when the rescues are attempted.



Fig. 7–12. Top left: A Griphoist brand tool uses mechanical advantage to pull a cable with an eye hook to slide or lift and object as much as 100 feet. There are several advantages to this tool over come-alongs, for example, its ability to switch from lifting to lowering without having to secure the load first. It is very smooth when working, and it makes no jerking movements. You can move an object precisely, because there are no gears that have to be locked to hold the load. Top right: An air chisel can cut duct work, metal sheets, appliances, and the like. This tool is good for freeing debris sections before hauling them away. Bottom left: A heavy-duty chain fall come-along can lift and lower, but it takes a lot of work to move an object. Bottom right: A cable come-along is good for pulling light loads and can also be used doubled up. It is good for pulling up items in tight openings where access is difficult.

Tool Cache

When the trailers come in and you have enough personnel, unload and set up your cache. Keep it outside the collapse safety zone, but keep as close as you can where it will not interfere with your rescue operations (fig. 7-13). The closer the tools are, the sooner you will get them and put them to use. Keep all the equipment in order; the same types of tools and equipment should all be in the same areas. For example, your cutting items should be in one area, all your shoring tools in another, and your first aid equipment in another.



Fig. 7-13. Make sure that all your staging tools and equipment are outside your collapse safety zone. It is important that your safety zone and main access and egress points are clearly marked. In this case the equipment is laid out on a tarp close to the operation. Group all your tools according to their type, and keep saws, shovels, pry bars, and the like in separate locations. This makes it much easier to account for the tools as well as find the ones you need quickly.

It is imperative that all of the tools and equipment that were used on the scene be rehabbed at the conclusion of your operations. When you get back to the barn, unload all of the trailers and rigs, account for all equipment, and make sure all tools and equipment are in working order. You must clean them, fuel them, and test them to make sure they all still work properly. Change the blades in any tools that need it.

Trailers

See figure 7-14 for various examples of trailers.



Fig. 7-14. Top left: One type of trailer can be towed behind a pickup or larger truck. Generally a trailer like this one can carry enough tools for your team to get started. This size trailer will let you operate for several hours before more or specific specialty tools are needed. It also is of sufficient size that you can store it the rear of a bay or even an outside lot when not loaded up. Top right: This portable trailer for lumber can be stored inside or outside. It should be covered with a tarp, leaving plenty of room for air to circulate around the lumber. Bottom left: A semi-tractor trailer, great for maneuvering around tight areas. It can also carry a large number of tools and equipment. Organize your compartments according to your cache of tools. Keep the same type of tools together whenever possible, and label each compartment with its contents. Bottom right: Here is a very well-organized trailer. Many of the tools are hung up, allowing easy access and easy identification.

Tool List for Collapse Rescue

Following is a list of the most common tools that will be needed by your search and rescue personnel. This list contains the bare necessities, but does not include everything you may use in collapse operations. Your team can expand the list when you feel they are ready to advance their training and operational level.

Hand tools

- | | | | |
|----|--------------------------------------|----|---|
| 10 | tape measures 16-ft 1-in wide blades | 2 | tape measures 100-ft steel |
| 6 | tape measures 25-ft 1-in wide blades | 4 | folding rules carpenter's 6-ft wooden rule |
| 8 | chalk lines | 4 | 5-lb chalk red and blue |
| 10 | framing hammers 24-oz straight claw | 10 | carpenter's tool pouches, leather |
| 10 | speed squares 12-in | 4 | 2-ft carpenter's framing squares |
| 4 | T bevel squares | 2 | 4-ft levels wooden |
| 2 | 4-ft smart levels | 4 | 2-ft levels wooden or aluminum |
| 4 | 2-ft smart levels | 12 | 6-in levels torpedo type |
| 2 | post levels | 24 | utility knives retractable blade |
| 12 | boxes carpenter's pencils | 12 | boxes lumber crayon, red, black |
| 8 | cats paws, nail pullers | 8 | wonder bars |
| 8 | pinch bars 36-in | 4 | 10-lb sledgehammers |
| 4 | 3-lb sledgehammers | 2 | 5-lb sledgehammers nonspark |
| 2 | 10.5-lb sledgehammers nonspark | 4 | handsaws, cross-cut 26-in 8 point |
| 4 | handsaws, tool box 15-in 9-point | 4 | hacksaws, 12-in with blades 24 teeth per inch |
| 4 | jab saws with blades | 4 | carpenter's hatchets |
| 4 | wood chisels 9-piece sets | 4 | cold chisels full sets |
| 6 | each C clamps, extra HD ½-, ¾-, 1-in | 12 | web clamps |
| 4 | shovels, short handle, square point | 4 | shovels, short handle, round point |
| 4 | shovels, long handle, square point | 4 | shovels, long handle, round point |
| 12 | shovels, entrenching type | 6 | wrecking bars 5-ft |
| 4 | wrecking bars 3-ft | 4 | pinch bars 5-ft |
| 6 | folding ladders 4-ft, 6-ft, 8-ft | 4 | pipe wrenches 24-in |
| 4 | pipe wrenches 12-in | 2 | mechanic's toolsets 225 pieces |
| 6 | tin snips, aviation, offset | 6 | tin snips, aviation, straight |
| 4 | bolt cutters 30-in, 24-in | 2 | bolt cutters 30-in case-hardened |
| 4 | bolt cutters 18-in ratchet type | 2 | pairs sawhorses Metal Mule |
| 12 | utility canvas bags | 8 | tool boxes strut foam |
| 8 | tool boxes metal | 12 | all-purpose boxes |
| 2 | timber hooks | 2 | can hooks |
| 4 | Dougal chains | 60 | steel pickets 1-in × 4-ft |
| 2 | cases orange spray paint | 2 | cases barrier tape |
| 4 | nails 8d duplex 50-lb boxes | 4 | nails 16d duplex 50-lb boxes |
| 1 | pipe cutter heavy-duty | | |

Hydraulic tools

- | | |
|--------------------------------------|-------------------------------------|
| 3 hydraulic jacks 2-ton low profile | 3 hydraulic jacks 6-ton low profile |
| 3 hydraulic jacks 10 ton low profile | 2 Hurst tool systems complete |
| 2 Rabbit tool | 2 portable power pumps 10-ton |

Electric tools

- | | |
|---|--|
| 3 circular saws 7¼-in worm drive | 3 circular saws 10¼-in |
| 12 24-tooth, carbide tip saw blades 7¼-in | 12 40-tooth carbide saws blades 10¼-in |
| 3 hammer drills, heavy-duty ½-in with bits | 3 drills, heavy-duty ½-in with bits |
| 3 drills, cordless ⅜-in, extra batteries | 6 reciprocating saws, heavy-duty |
| 3 screw guns, heavy-duty high-torque | 3 demo-hammers, heavy-duty 13-amp |
| 3 rotary hammers, heavy-duty 1 ½-in | 2 portable band saws, heavy-duty |
| 2 angle grinders, heavy-duty 4 ½-in | 2 die grinders ¼-in |
| 2 power miter boxes 15-in | 6 80-tooth blade carbide |
| 2 miter saw stands | 1 table saws 10-in |
| 6 40-tooth blade saw blades 10-in carbide | 1 band saw 14½-in |
| 4 chain saws 16-in bar | 4 spare bars |
| 12 spare chains, carbide | 12 spare chains regular |
| 2 rebar cutters, 1-in capacity | 3 5000 kW generators |
| 4 1,000 kW generators | 3 2500 kW generators |
| 8 Heavy-duty extension cords 100-ft with reel | 6 12-volt fluorescent light portable |
| 10 flood lights 500 watt | 12 fire power four outlet junction boxes |

Power-actuated tools

- | | |
|---------------------------------------|------------------------------------|
| 2 Hilti® DX600N power-actuated hammer | 2 Hilti DX451 or equivalent |
| 400 DS HD pins with washers 2-in | 400 DS HD pins with washers 3 ¼-in |
| 400 boosters, red #5 | 400 boosters, purple #6 |

Pneumatic tools

- | | |
|--|--|
| 3 air nailers 6d-16d full-head nailer | 4 air chisels, heavy-duty |
| 2 whizzer cutoff saws | 2 sets maxi-force urban search and rescue (US&R) air bag kit |
| 3 Paslode® gas-operated nailer, 6d–16d | 3 air compressors pancake style |
| 3 air compressors | 2 air source carts |
| 2 ventilation fans 1,000 cubic feet per minute | 1 set high-lift, low-pressure air bags |

Gasoline-powered tools and other equipment

- | | | | |
|----|---|----|---|
| 4 | chain saws 2, 24-in, 2, 16-in | 2 | partner saws # 650 |
| 3 | oxy-acetylene, MAPP or gasoline torches | 2 | exothermic torches |
| 2 | surveyor's transits | 2 | search cams |
| 2 | SnakeEye™ fiber-optic system | 2 | thermal imaging cameras |
| 4 | hot sticks | 4 | binoculars |
| 2 | first aid kits large | 4 | multigas detector meters |
| 2 | air knives | 10 | cases duct tape |
| 12 | haul buckets | 2 | ½-in and ¾-in utility rope, 100-ft each |
| 1 | Gasoline operated core cutter | 1 | acoustical listening device |
| 2 | laser measuring devices | | |

Lifting and rigging equipment

- | | | | |
|---|---|---|---|
| 6 | each ½-in wire rope slings 6-ft, 10-ft, 14-ft | 4 | each synthetic slings 6-ft, 8-ft, 12-ft |
| 4 | come-alongs 2-ton cable | 4 | come-alongs 4-ton chain |
| 2 | grip hoists 1, TU32 1, TU28 | | |

Note: Concrete-breaking tools are not included in this list. If large potential concrete buildings are in your response area, then these tools are appropriate, and additional training should be given to the team who will be using them.

Introduction

The Definition of Collapse

The definition of collapse is to shrink together suddenly, to cave in, fall in, break down, fail suddenly, fold, or push together. The modern word *collapse* is derived from the Latin word *collabi*, which means falling in ruins. The Romans had a word for it, so they must have experienced collapses on more than one occasion. For the last several thousand years, there have been structures suddenly falling and trapping or killing victims. The Code of Hammurabi, dating back to the ancient Babylonia of 1700 BCE, had a section stating that if the collapse of a structure occurred, then the designer and builder of that structure would suffer the same consequences that the collapse caused. If that was the case today, it would probably eliminate most of the shoddy construction that has caused many contemporary collapses. The word that keeps being repeated here when the word collapse is mentioned is “suddenly.” Although structural collapse usually occurs quickly (large structures can virtually fall in seconds), it is rare that they happen without any type of warning. Depending on the type of structure, the building materials, and the condition of the structure, there may be several subtle or obvious collapse warning signs. This book discusses in detail the common warning signs and what to do when they are encountered.

The economic situation of the last several decades has left whole areas of inner cities neglected, unmaintained, and, in some drastic cases, totally abandoned. This has precipitated an alarming increase in the number and severity of structural building collapses throughout the nation. Although neglect of building maintenance remains one of the primary causes of structural collapse, many other factors can cause the structural collapses that occur in communities all over the United States. These include explosions; collision impact; overloaded floors or roofs; vibrations; improper alterations and renovations; fire; and natural disasters such as earthquakes, hurricanes, tornadoes, mud slides, wind storms, heavy snow loads, and the like. Another cause of structural collapse occurs during the initial phases of building erection, due to either faulty design or improper or unsafe construction practices. The potential for deadly building collapse exists in every town and city in the nation, and your fire department should be trained and prepared for this

type of emergency. Collapse operations are difficult and hectic at best. If your department is not properly prepared, disastrous results can occur for civilians and rescue personnel alike.

Collapses have been occurring since humans started building structures for shelter. Even the great Egyptian builders had their share of troubles. There is unmistakable evidence that the pyramid at Meidum in Egypt collapsed due to structural defects. Experts have concluded that the collapse was brought on by one of the most common causes, foundation failure. The cathedral at Beauvais, France, is another example of large structures failing while being erected. As early as the 14th century, documented evidence of structural problems existed for this structure. Because of the prevalence of these incidents, building construction is a major part of collapse training. How a building is erected will tell us how the structure will collapse. When responding to an incident, especially when parts of the structure are still standing after the initial collapse, it is essential to know how the building was constructed.

This book will provide a practical, hands-on approach to operating safely and effectively in collapse rescue situations. Discussion will be chiefly directed toward one of the most common types of structures around the country, wood and brick-and-joist (ordinary-constructed) buildings, known as unreinforced masonry (URM) construction. Various types of shoring and cribbing techniques vital to collapse rescue operations, as well as void size-up, safety at collapse operations, tools used in voids, and void procedures, will be explored.

This book is designed to be a source of information and can be changed or adapted to fit your department's specific needs. Team operations will be laid out for several situations. These guidelines are already in use in several areas and have been working successfully, but they should be adapted for your needs.

When a major collapse occurs in your jurisdiction, your personnel must be qualified to handle it. If you have limited personnel, rescue operations will be affected. Structural collapse rescue is a multifaceted operation. Basic firefighter training and collapse overview training provides nowhere near enough information necessary to operate safely in a void rescue or a structural stabilization situation. Ideally, this book will help to expand your knowledge in order to operate safely in these types of scenarios.

As the country gets older, so do its buildings. Buildings have a life cycle just as humans do. They start to age the minute they are erected. In some of the world's bigger structures, notably cathedrals, it is not uncommon for the foundation to be anywhere from 50 to 100 years older than the roof. Imagine having to maintain and repair the walls of the foundation even before the roof is on the building. It is a constant fight against the elements of nature and the ever-present pull of gravity. If structures are maintained and repairs are promptly and properly made, most will last for a long time. However, if improperly maintained, they will deteriorate rapidly until structural integrity is compromised, and they can fall under their own weight. In recent times, whole areas of inner cities have been left abandoned and unmaintained. This has resulted in the rapid decay of the structures, precipitating an alarming increase in the number and severity of building collapses. Unfortunately, repairing these damaged and aged structures is not a priority. As a result, they will keep coming down on a fairly frequent basis. As all of the nation's cities get older, the collapse of older buildings will start to become an issue for everyone. The potential for building collapse exists in every community, and all fire departments must be prepared to operate in this kind of emergency.

Unfortunately, over the last several years some terrible terrorist attacks have occurred in some of the more populated urban areas all over the world. The World Trade Center in New York City and the Murrah Federal Building in Oklahoma City are two of the most well-known incidents. Having operated at both incidents, I know firsthand the enormity of these tragedies and the suffering of the innocent victims. These are overwhelming situations that can tax even the largest of fire departments. Your community must be prepared. When incidents of this magnitude occur, the first place the populace looks for help is the local fire department. They will reach out to you for immediate help. The one thing you do not want is to be unprepared. Training and preplanning are a necessity for the larger structures in your response area. Do not be caught unaware! In both of the incidents mentioned here, firefighters responded to help friends and relatives alike—it will play havoc with your mind when you know the structure you are responding to will affect you personally. Be prepared—it is your obligation to do so.

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